PROCEEDINGS OF THE BEAUFORT SEA GRANULAR RESOURCES WORKSHOP

FEBRUARY 13 AND 14, 1992

SPONSORED BY:

INDIAN AND NORTHERN AFFAIRS CANADA NATURAL RESOURCES AND ENVIRONMENT BRANCH

Part of the Northern Oil and Gas Action Program
(DSS File No. 038ST.A7134-0-0037)

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Edited By:

Neil R. MacLeod, P.Eng.
EBA Engineering Consultants Ltd.
Calgary, Alberta

(EBA Project No. 0306-34786)

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PREFACE

The major Beaufort Sea petroleum operators, in their 1983 submission to the Beaufort Environmental Assessment and Review Process, indicated a potential demand for up to 700 million cubic metres of granular material. Although it was known that substantial quantities of sand-sized material existed at the seafloor, the distribution of offshore gravel resources was less certain. At about the same time, a regional overview study of the supply/demand situation for offshore granular resources was undertaken by the Department of Indian Affairs and Northern Development (DIAND) with the co-operation of the industry. The main finding of the study was that proven resources fell far short of the forecast long-term demand for an estimated 35 million cubic metres of gravel.

In order to address this concern, a research project was initiated as part of the Northern Oil and Gas Action Program (NOGAP). NOGAP is intended to advance government preparedness for major hydrocarbon development in Canada's northern territories. This meant acquiring the knowledge and analytical capbility to make appropriate decisions concerning major northern development proposals. NOGAP funds have been used to accelerate work on current projects or to undertake new activities which existing budgets could not accommodate.

NOGAP Project A4, Granular Resources Inventory and Management, began in 1984/1985. Its objectives were to ensure that adequate geotechnical, hydrographic and other technical information is available for granular resources management and to provide detailed information on each significant borrow source in the region as is required for conservation and effective utilization. Following a three year hiatus, NOGAP was revived in 1990/1991 and is expected to continue until 1993/1994. A total of 17 sub-projects detailing with offshore granular resources in the Beaufort Sea have been completed, to date, under NOGAP. This work has been guided since 1985/1986 by an informal working group that included representatives of each of the three major Beaufort operators and the Geological Survey of Canada (GSC).

The NOGAP A4 project has worked towards a regional granular inventory by conducting several studies annually to improve the scientific and geotechnical data base. These studies were intended to complement the work of industry and government by focussing on the high quality granular deposits that might be in greatest demand and by tying-in these separate site specific studies to provide a better understanding of the regional inventory. A major effort has been made in this project to catalogue and compile most of the data previously collected by the main Beaufort petroleum operators into a series of computer data bases that have recently been linked with a digital mapping system to provide ready access. This information has been used to prepare several regional resource assessments of granular material sources in the Beaufort Sea. These studies have been conducted in co-operation with regional studies undertaken by the GSC to establish the geological framework for the Beaufort Region.

Since the initial studies, the Beaufort petroleum operators have expressed concern that much of the higher quality gravels have been used as general fill for island construction. In addition, there has been a greater demand for limited supplies of high quality sands and requests have been made for the exportation of Beaufort granular resources to Alaska. Meanwhile, there has been discussion about treating granular resources like mineral resources by allowing exclusive exploitation rights. These events have placed increased pressure on the department to effectively inventory and manage the remaining offshore deposits. With NOGAP winding down and industry activity in the region waning, there was perceived a need to bring together those who have been part of Beaufort exploration activities and those who may be future participants. This workshop was intended to provide a forum to review the existing information and to identify future research and study requirements.

This workshop could have not been possible without the co-operation of both industry and government. The kind offer of ESSO Resources Canada Ltd., through Jeff Weaver, to provide the comfortable meeting facilities is greatly appreciated. The support and encouragement of several representatives of ESSO, Gulf and Amoco and paticularly, the continuous involvement of Kevin Hewitt (Amoco/CanMar) over the years have been critical to any successes realized. In addition, Steve Blasco of the GSC has been a constant "sounding board" and advisor. Acknowledgement is given also the technical paper authors and presenters for the excellent efforts under a tight schedule. Finally, the skills and experiences of the workshop organizers, Neil MacLeod and John Lewis have been demonstrated in their crafting of a balanced and interesting program of technical papers and thoughtful discussion. To all of these, a sincere "thank you".

Robert J. Gowan P.Geol.
Geotechnical Advisor
Northern Granular Resources Program
Indian and Northern Affairs Canada
Ottawa, Ontario K1A 0H4

FORWARD

A two day workshop was held in Calgary in mid-February, 1992 to review and discuss technical issues relating to granular resource exploration in the Beaufort Sea. The workshop was sponsored by Indian and Northern Affairs Canada as Sub-Project A4-26B of the Northern Oil and Gas Action Program (NOGAP). Participants included Beaufort Sea operators, government regulators and researchers, consultants and potential users of the data. The sessions were co-chaired by Mr. Neil MacLeod (EBA Engineering Consultants Ltd., Calgary) and Mr. John Lewis (Lewis Geophysical Consulting, Armdale, Nova Scotia).

The first day of the workshop comprised twelve prepared presentations. Nine of these were reports by consultants of work performed for NOGAP Project A4 between 1984 and 1991. Part 1 of the Proceedings presents the results of six regional studies and Part 2 provides summaries of three research and data handling assignments. Part 3 includes three other presentations which were made on the first day and intended to provide some input from outside the NOGAP project.

The second day of the workshop proceeded as a round-table discussion. It was attended by the presenters from the previous day and INAC's Program Manager, Mr. Bob Gowan. The discussions were focused on identifying future requirements for granular resource exploration, equipment development and data handling. Part 4 of the Proceedings provides an edited precis of these discussions. The last section of the Proceedings provides the editor's interpretation of direct recommendations (46) arising in the round-table discussions.

Editing of the prepared presentations was minimal. They were changed to a common format and titles were added to figures where needed. The round-table discussions was edited to shorten the text and make it more readable. The shortening process entailed consolidating related discussions on a topic which may have occurred at two or more periods of the day, deleting off-topic comments and questions, and paraphrasing some long winded rambling into more concise prose. In all, the original transcripts have been reduced by approximately 55%.

Neil MacLeod
EBA Engineering Consultants Ltd.
Calgary, Alberta

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PART 1

REPORTS ON NOGAP REGIONAL STUDIES

The Western Beaufort (Yukon) Continental Shelf
(NOGAP Project A4-05)

Presented By J.F. Lewis
Lewis Geophysical Consulting
Armdale, Nova Scotia

1.0 Introduction

During 1986, an interpretation and integration of the previously collected bathymetric, geophysical and geological data from the western Beaufort Shelf was undertaken by Earth & Ocean Research Ltd. for the Department of Indian and Northern Affairs (INAC). The investigation was to provide an overview of the granular resource base of this area to assist in planning of future exploration studies to delineate granular materials for use in the on-shore or off-shore construction by industry or government.

Figure 1 shows the location of the study area consisting of the western Beaufort (Yukon) Shelf or Natsek Plain (O'Connor, 1982 - physiographic province) extending from the shoreline to the shelf edge at approximately the 80 m water depth contour. The region is bounded on the west by the Yukon/Alaska border at longitude 141° W and on the east by the Mackenzie Trough and the eastern edge of Herschel Island at approximately longitude 139° W. The region constitutes approximately 5,000 km^2.

2.0 Data Bases

Prior to 1984/1985 there was little data available for the western Beaufort Shelf region. CHS bathymetric chart 7601 indicated a few widely spaced sounding lines with non-systematic coverage. A total of 53 grab samples and 4 piston cores had been taken by the GSC within the boundaries. Grain sizes and broad distribution mapping of the surficial sediments had been presented in Pelletier (1975), Vilks et.al., (1979) and Pelletier (1985). A single geotechnical borehole, Natsek 4, was drilled in 1978 and textural descriptions and test results were presented by McClelland Engineers Ltd. (1979).

A significant increase in the data base occurred in 1984 when a combined hydrographic and geophysical survey was conducted from the M.V. Banksland by the CHS and the GSC. This survey yielded 14,055 km of heave compensated echo sounder data, 820 km of 10 in^3 air gun, 50 Khz side scan and 3.5 Khz profiler data, 14 piston cores to a maximum 1.5 m penetration and 187 Shipek grab samples which have only been visually described (no quantitative grain size analysis). The results of the hydrographic survey are presented in

McGladrey (1984) and resulted in the preparation of CHS field sheet WA10167. A preliminary interpretation of the geophysical and geological data is presented in Meagher (1985).

In 1985, an additional 1,950 km of 10 in^3 air gun, 3.5 Khz profiler and EG&G boomer data were collected from the C.S.S. Tully by Geomarine Associates. No sediment samples were collected during this program. Approximately half of these 1985 data lines were collected from within the area of the present study, the remainder covers an area to the north and east. The field operations are reported in Fehr (1986).

Also during the 1985 field season, a geotechnical borehole (GSC-1) was drilled from the M.V. Broderick on the outer shelf (EBA Engineering Consultants Ltd., 1986). This borehole, located at 70°08'23.91"N, 140°28'17.86"W, was drilled to a sub-seafloor depth of 52.6 m. Additionally, a number of boreholes were drilled for industry on the Alaskan shelf. Five of these are located near the site and reference is made to field notes of these borings.

In total the limited direct samples data base consisted of 240 grab samples, 18 piston cores and 2 geotechnical boreholes, as shown in Figure 2. The high resolution geophysical data set shown in Figure 3 totalled 2,770 km of high resolution seismics which was supplemented by selected echo sounder data from a 14,055 km data base (not plotted here).

At the time of writing of this study, EOR was also working on a Quaternary geological synthesis of the seismo-stratigraphy of the area (Lewis and Meagher, 1991) and Mr. Jim Shearer was analyzing the side scan sonar data for ice scour and other seabed transport information (Shearer, 198_). Challenger Survey was also developing a 3-D presentation of the bathymetric information for the region (Challenger Surveys, 198_) and McGregor Geosciences Ltd. had prepared a hazards report over the Edlok well site. Data from these studies, though preliminary at the time of writing of this report, have been incorporated were relevant to the discussions here.

3.0 Site Descriptions

The western Beaufort (Yukon) Shelf had been designated the Natsek Plain by O'Connor (1982) and was noted to be primarily a fine grained sedimentary sequence that did not correlate with the general geological model for the eastern Beaufort Shelf (O'Connor, 1980). Lewis and Meagher (1991) developed a comprehensive seismo-stratigraphic description of the area that indicates the Upper Tertiary and Quaternary section within the region.

3.1 Bathymetry and Physiography

Figure 4 is a detailed bathymetric contour map of the Yukon Shelf developed by a physiographic features oriented re-contouring of the 1984 hydrographic survey data presented on CHS field sheet WA-10167. The shelf has a regional slope of 1:833 to the north. The surface slopes northward in the coastal and mid-shelf regions and trends increasingly toward the northeast as the shelf edge is approached. The transition from shelf to slope is abrupt and occurs approximately at the 80 m water depth contour. The shelf edge is noticeably regular with no prominences or incisions, possibly the result of planation by glacier ice restricted to the trough during the Wisconsin Glaciation.

The major physiographic sub-regions of the Yukon Shelf have been defined in this program and are outlined in Figure 5 and given informal names. Two ridges dominate the shelf morphology. The In-Shore Ridge extends from due west of Herschel Island for a distance of approximately 60 km. It is approximately enclosed by the 24 m water depth contour and is about 4 km wide. The Off-Shore Ridge is a larger feature and occupies the outer north facing shelf from the 50 m contour to the shelf edge. This ridge extends west onto the Alaskan shelf and within the study area the ridge is 66 km long and 14-18 km wide. The axis of the ridge is situated near the southern flank were a minimum water depth of 37 m is noted. A narrow linear spur ridge extends from its northeast corner in a northeast direction to the shelf break.

Topographically, the Outer Ridge is irregular with numerous linear and sinuous superimposed shoals of one to several metres in local relief. These shoals form a second ridge complex named the "Natsek Ridge" which is sub-parallel to the main ridge and displays a branching pattern suggestive of dendritic drainage controlled formation. This pattern is most apparent on the 3-D representations constructed by Challenger Surveys and depicts four or five tributary ridges that coalesce with the trunk ridge at their eastern ends. These ridges die out in a westerly direction and do not extend beyond the Alaska-Yukon Boundary.

There are numerous smaller shoal features observed on the shelf though they are predominantly concentrated immediately north of the Inner Ridge. There are noticeably fewer shoals in the mid-shelf region, though those present are thought to be relict stamuki shoals developed as the seas encroached across the coastal plain. A few shoals near the edge of the Mackenzie Trough just south of the Outer Ridge exhibit significantly higher relief and slope which may represent limited exposure of coarser, more resistant materials lying between Units L and M. Alternately, these shoals could possibly be morainal deposits.

The Outer Trough separates the two ridges. It is broad and flat bottomed with small mounds of 2 to 5 m elevation scattered over its floor. The bottom of this trough descends to the east at a low gradient where it is truncated as a sort of hanging valley into the Mackenzie Trough. Maximum depths in the Outer Trough are 58 m. The In-Shore Trough is a smaller feature enclosed by the 24 m contour with a maximum depth of 27 m. It is 36 km long and 6 km wide at its maximum. The In-Shore Ridge has been interpreted as a series of stamuki shoals constructed by sour action of the winter ice pack as it rotates against the shore fast ice. Sub-surface evidence suggests that the stamuki shoal has developed on an older shoal feature.

3.2 Surficial Cover

The surficial sedimentary cover on the Yukon Shelf represents a conflicting interpretational situation. From the sub-surface seismo-stratigraphy and borehole data that is available, all of the strata from just beyond the near shore zones to the off-shore portions of the shelf consists of fine grained materials with very low concentrations of sands or gravels indicated. From the surficial grab sample information, the indications suggest that the inner shelf is predominantly a silty-clay facies while the samples and side scan data for the off-shore region indicate these regions to be a sand-gravel dominant facies. Based on this discrepancy, it is concluded that the coarser off-shore facies is a thin lag deposit which is too thin to resolve with the high resolution seismics and has been transported into the area by ice rafting.

Figure 6 is a map of the bottom sediment distribution of the Yukon shelf that was presented by Pelletier (1985) based on the pre-1984 sample data base (approximately 50 samples). This map was compiled using an analyzed data set and could not be modified using the qualitative descriptions of the samples collected during the 1984 surveys.

Jim Shearer (personal communication) has interpreted high gravel concentrations from the side scan data to be restricted to a narrow zone that runs the length of the Mackenzie Trough shelf edge. These data also indicate extensive areas that are dominated by sand ripples and mega-ripples. The sand ripples are observed within the eastern and central Outer Trough while the mega-ripples occur in a narrow linear zone sandwiched between the eastern edge of the gravel zone and the Mackenzie Trough shelf edge. The distribution of these zones has been outlined on the granular resource map of Figure 10 as it was not felt that the qualitative descriptions could be used to modify the Pelletier maps, though this information is considered important to the granular resource assessments.

3.3 Subsurface Geology

The sedimentary section beneath the shelf region thickens to seaward and rests unconformably and para-conformably of a region-wide Miocene erosion surface. The sub-surface sedimentary strata form a predominantly fine grained clastic wedge laid down under shelf, coastal, sub-aerial and glacial environments. These strata correlate with the Upper Iperk Sequence on the eastern Canadian Beaufort Shelf and the Gubik formation on the Alaskan Beaufort Shelf. The surficial cover over the greater part of the shelf consists of a stiff to soft, grey clayey silt to silty clay with various admixtures of gravel. High concentrations of gravel and sand occur seaward of the river mouths and in a broad apron that follows the shelf edge. The gravels at the river mouths are off-shore extensions or re-worked components of alluvial fans on shore. The off-shore gravel concentrations contain significant proportions of exotic clast lithologies and indicate at least a partial provenance from the Canadian Arctic Islands. These lithologies suggest an ice rafted, drop stone origin for these materials.

The present seafloor of the shelf area is erosional in character and represents the latest shelf wide unconformity surface as evidenced by truncation of the sub-surface strata at this surface. With the possible exception of the near shore zone (Unit Q within the In-Shore Trough areas), there is no indication that present day sedimentation is occurring on the shelf. Erosion and sediment redistribution by current and wave action and ice keel scouring is evident and may have removed a significant amount of the sedimentary section. Age determinations based on the limited boreholes available suggest that the exposed sediments on the seabed are of Mid- to Late Pleistocene in age (50,000 to 80,000 b.p.).

The seismo-stratigraphic sequence underlying the Yukon Shelf is interrupted by numerous unconformity surfaces, several of which display channel development and record a history of a least six to ten regressive and transgressive episodes since the Miocene that have alternately sub-aerially exposed and drowned the shelf. At least two of the unconformity surfaces form apparent buried shoreline topographies near the present day shelf edge suggesting sub-aerial exposure affected the entire shelf at various times (Horizons 12 and 15). The net effect of these cycles has been a progradation of the shelf edge toward the north. Figure 7 shows a north-south transect line across the shelf indicating the seismo-stratigraphic sequences associated with this shelf development. A total of 11 seismo-stratigraphic units are identified on the shelf and 8 are exposed on the seabed. This sequence of sub-surface sedimentary units have been identified and designated with alpha codes which range from Unit G (below Horizon 7) at the base (Miocene pre-unconformity materials) to Unit P (above horizon 15) which represents the youngest mappable (with the present data set) sediments preserve at the shelf edge (possibly as much as 50,000 years old). Figure 8 outlines the relationship of the various stratigraphic units within the western

Beaufort (Yukon) Shelf sequence and provides a tentative age correlation of the respective units compared to the age dating from the GSC-1 borehole and projected correlation to work completed on the Alaskan Beaufort shelf and North Slope regions. Unit Q represents a localized, ponded, overlying unit that is restricted to the In-Shore Trough region and cannot be stratigraphically position within the general sequence because of its isolated extent. This unit is observed to disconformably lie on top of the contemporaneous Units R and L in this near shore region. Figure 9 is a map of the exposure of these units as they intersect the seabed. There is likely a very thin surficial veneer over these exposures which was below the resolution capabilities of the seismic systems employed in the mapping process and represents the, apparently, unrelated surficial lag materials mapped in the surficial sediment distribution map of Figures 6 and 10.

3.4 Depositional Summary and Provenance

The sub-surface sediments on the Yukon Shelf represent a predominantly fine grained clastic wedge sequence characteristic of continental shelf outbuilding. These materials were predominantly deposited under marine and near shore marine conditions with a fine grained source of supply from the south or possibly along shore from the east or west. As has been outlined above, these materials are presently being eroded at the seabed and the limited borehole evidence indicate a very sparse content of coarser materials. As a result, these sediments are not believed to represent a source for lag borrow materials.

The sediments presently residing on and very near the seabed of the Yukon Shelf indicate that the relation between locale, bathymetry, stratigraphy and sample texture is not straightforward and that distribution is controlled by several independent mechanisms.

The present day predominant source of new sediments to the Yukon Shelf is the coastal retreat on-going along the Yukon coastline. The coastline west of Komakuk Beach and extending almost to Clarence Lagoon is dominated by fine grained lacustrine sediments. Coastal erosion is documented along this coastline (Rampton, 1982) and similar regions on the Alaskan North Slope record average rates of retreat that are approximately 5.4 m/year and locally reaches 18 m/year (Reimnitz et.al., 1985). These new sediments are not observed to be collecting in any significant deposits, however, on the shelf and it is presumed that the fines are virtually all being swept of the shelf to be deposited in the Mackenzie Trough and over the northern shelf edge.

The gravels and sands of the Coastal Zone are relict and were deposited as alluvial fans at a time of lower sea level. They are presently being re-worked into marine land forms of bay mouth bars, islands and spits and they are also being transported off-shore a minimal distance where they form a thin veneer on top of the fine grained lacustrine or lagoonal materials which occupy the In-Shore Trough.

The coarse grained materials found on the Middle Shelf are generally, though not always, located on shoals and the majority of shoals in this region are composed of fine grained materials. The sands and gravels in this region are unevenly distributed and generally occur in a bimodal distribution with mud. Since there appears to be no sub-surface source for these materials, it is presumed that these materials have been transported to the middle shelf regions from the alluvial sands by ice rafting with subsequent concentration through winnowing on the tops of the shoals.

This mechanism is invoked on a larger scale for the gravels on the Outer Shelf where the surficial veneer of coarse materials is ubiquitous. The coincidence and restriction of this resource to the Outer Shelf along with the exotic lithologies, suggesting an Arctic Island source, imply that these material were most likely transported to the shelf from off-shore, possibly at a time of lower sea level when access by ice was restricted to the 40 to 50 m isobath.

4.0 Granular Resource Model and Evaluations - Distribution

Figure 10 presents the interpreted distribution of potential granular resources for the Yukon Shelf area. The description of potential aggregate concentration is subdivided into three geographic zones; a Coastal Zone where coarse aggregates are drowned extensions of on-shore deposits, a Middle Shelf Zone dominated by lag deposits localized on shoals and an Outer Shelf Zone where a combination of outcrops of coarse material and concentrations of ice rafted detritus are the likely sources of coarse materials.

Using these distinctions, 20 prospects have been mapped over the entire shelf with prospects 1 to 4 being representative of the Coastal Zone, 4 through 15 being in the Middle Shelf Zone and 16 through 19 being in the Outer Shelf Zone. Prospect 20 constitutes the entire Outer Shelf Zone, though has not been incorporated into the following volume estimates because there is currently virtually no evidence available for a thickness estimate of the coarser materials in this region.

The selection and identification these prospects has been defined, at least initially, based on the sample descriptions. Within the Coastal Zone, the areal extent of the prospects has been extended using the bathymetric data and very limited seismic coverage available in the region. In the Middle Shelf Zone, the bathymetry contours and field profiles were used to both map and evaluate prospects supplemented by micro-profiler records, when available, in order to attempt to establish a probable depth of the resource. While the entire Outer Shelf Zone is identified as "prospective", specific areas have been designated prospects based on likely topography (prominent shoals), seismics or topography plus samples in order to narrow the search areas to some degree. This is done while recognizing that an unique relationship between shoal areas and coarse materials is not established from this study for the Outer Shelf area.

5.0 Resource Prospect Granular Volume Estimates

There are no "proven" resources defined within the region. Given the conflicting nature of the cores, boreholes and seismics against the available grab sample data, it is obvious that the grab samples cannot be taken as representative of the substrate to any depth greater than a few centimetres.

Table 1 summarizes the prospects within the western Beaufort (Yukon) Shelf study region indicating the areas of each resource prospect with an estimated thickness for each along with the probable or prospective reserve best estimated volume calculations. A confidence factor is included for each prospect based on a review of the sample, bathymetric and seismic evidence available on each site combined with an interpretive assessment of these data. A detailed discussion of each prospect region is included in the original report, though will not be repeated here.

Prospects 1 to 4 and 18 have been evaluated as "probable" resource areas with an estimated potential total reserve of 556 to 841 million cubic metres of gravel and sand mixture. The remaining prospects are considered "prospective" resource areas with a total estimated volume of 329 million cubic metres. The region in-shore of the 10 m isobath extending to the shoreline has been designated as a probable reserve with a potential volume of 444 - 740 million cubic metres. This region has been separated out from the others because unusual dredging techniques would be required within this near shore region and it may or may not represent an economically recoverable resource for the region.

6.0 Conclusions

From a study of the sample, bathymetric and geophysical data available on the Yukon Shelf, the following conclusions can be drawn:

- There are no proven deposits of coarse material within the study due primarily to a lack of borehole control.

- Probable areas include four drowned alluvial fan deposits adjacent the coastline and a grouping of shoals of possibly resistant substrate or morainal material situated on the east central edge of the shelf.

- The total volume of material identified as probable resource from the 10 m isobath to the shelf edge is 557 - 842 million cubic metres.

- An additional 444 - 740 million cubic metres of probable resource is calculated for the area lying between the 10 m isobath and the shoreline.

- Prospective areas include a number of shoals on the Middle Shelf and virtually the entire Outer Shelf from the 40 - 50 m isobath to the shelf edge.

- This latter area is not satisfactorily resolved from the data at hand and it is possible that the coarse grained deposit may be a surficial veneer of only a few centimetres thickness over most of the area.

- The prospective areas, exclusive of the general area of the Outer Shelf, represents a total resource volume of 329 million cubic metres.

- The Outer Shelf zone has an area of 1,400 million square metres, but no thickness is attributed to the deposit at this time.

- The quality of the granular material requires more extensive analyses of the grab samples. From the data at hand it appears that the quality in terms of grain size and sorting will be highest on the drowned alluvial fan deposits and the possible moraine deposit on the east central shelf edge and elsewhere will be deteriorated by high admixtures of fine grained material.

Table 1 - Summary of Granular Resource Potential On The Western Beaufort (Yukon) Continental Shelf

Prospect	Area $m^2 \times 10^6$	Average Thick (m)	Probable $m^3 \times 10^6$	Prospective $m^3 \times 10^6$	Confidence Level
Beach Zone (volume not included in total)					
1B (0-10m)	73.99	6-10	444-740		High
Coastal Zone					
1 (10-20m)	71.35	6-10	428-713.5		High
1A	74.65	-			Moderate
2	2.4	2.5	6.0		High
3	2.9	2.0	5.8		High
4	25.1	2.0	50.2		High
Middle Shelf Zone					
5	13.0	2.0		26.0	Moderate
6	1.8	1.5		2.7	Moderate
7	-	-			Low
8	6.5	-			Low
9	2.9	2.0		5.8	Low
10	1.1	2.0		2.2	Low
11	3.4	1.0		3.4	Low
12	4.0	0.5		2.0	Low
13	1.0	0.5		0.5	Low
14	11.0	0.8		8.8	Low
15	2.7	0.7		1.9	Low
Outer Shelf Zone					
16	3.0	2.0		6.0	Moderate
17	-	-		-	Low
18	16.7	4.0	66.0		High
19	31.7	8.5		269.5	Moderate
TOTALS	**275.2**		**556.0-841.5**	**328.8**	

Note: The entire Outer Shelf (Prospect 20) is not included in the above summation pending additional information on the nature and thickness of the coarse grained veneer. It is, however, considered "prospective" and includes an area of 1,400 million square metres.

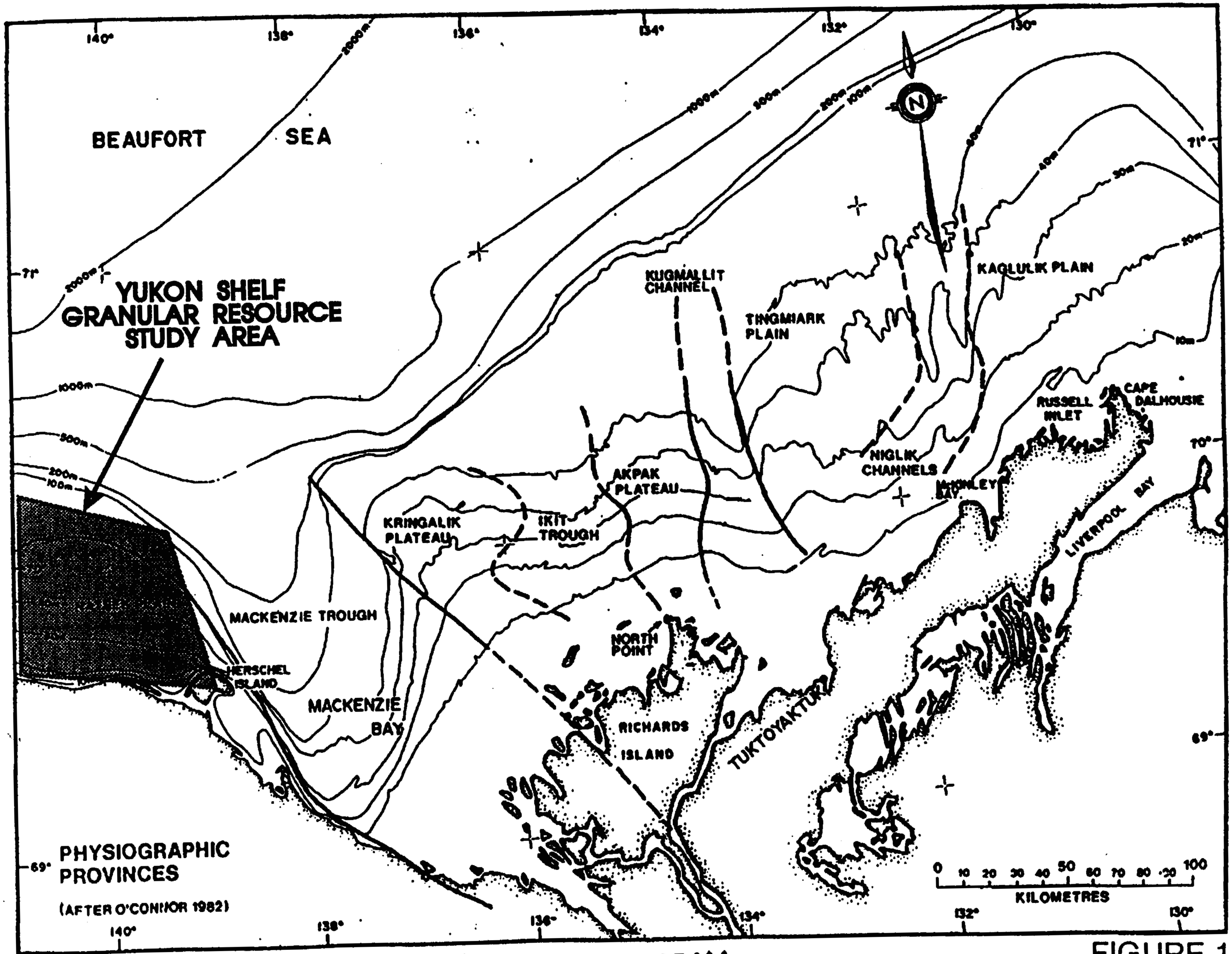
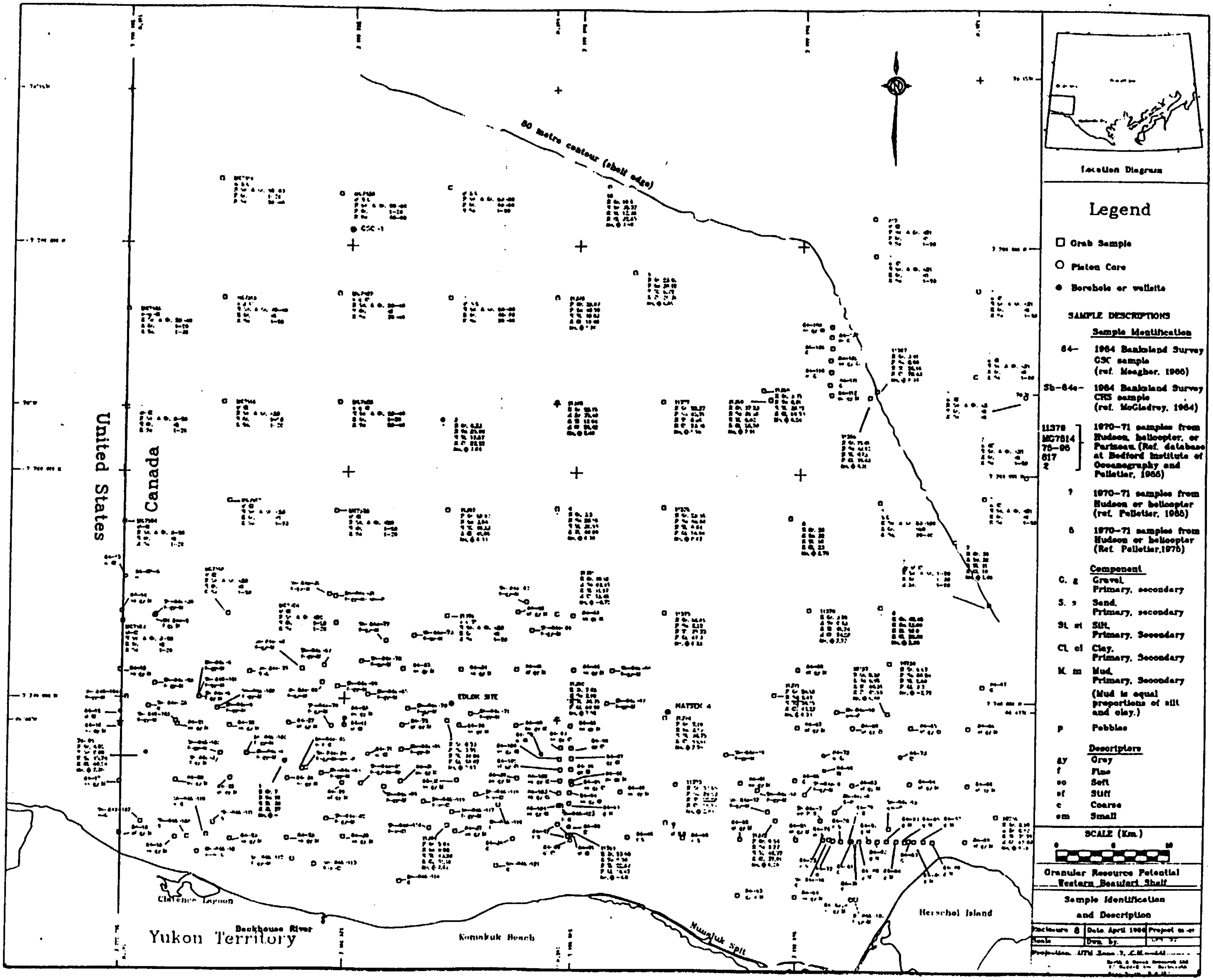


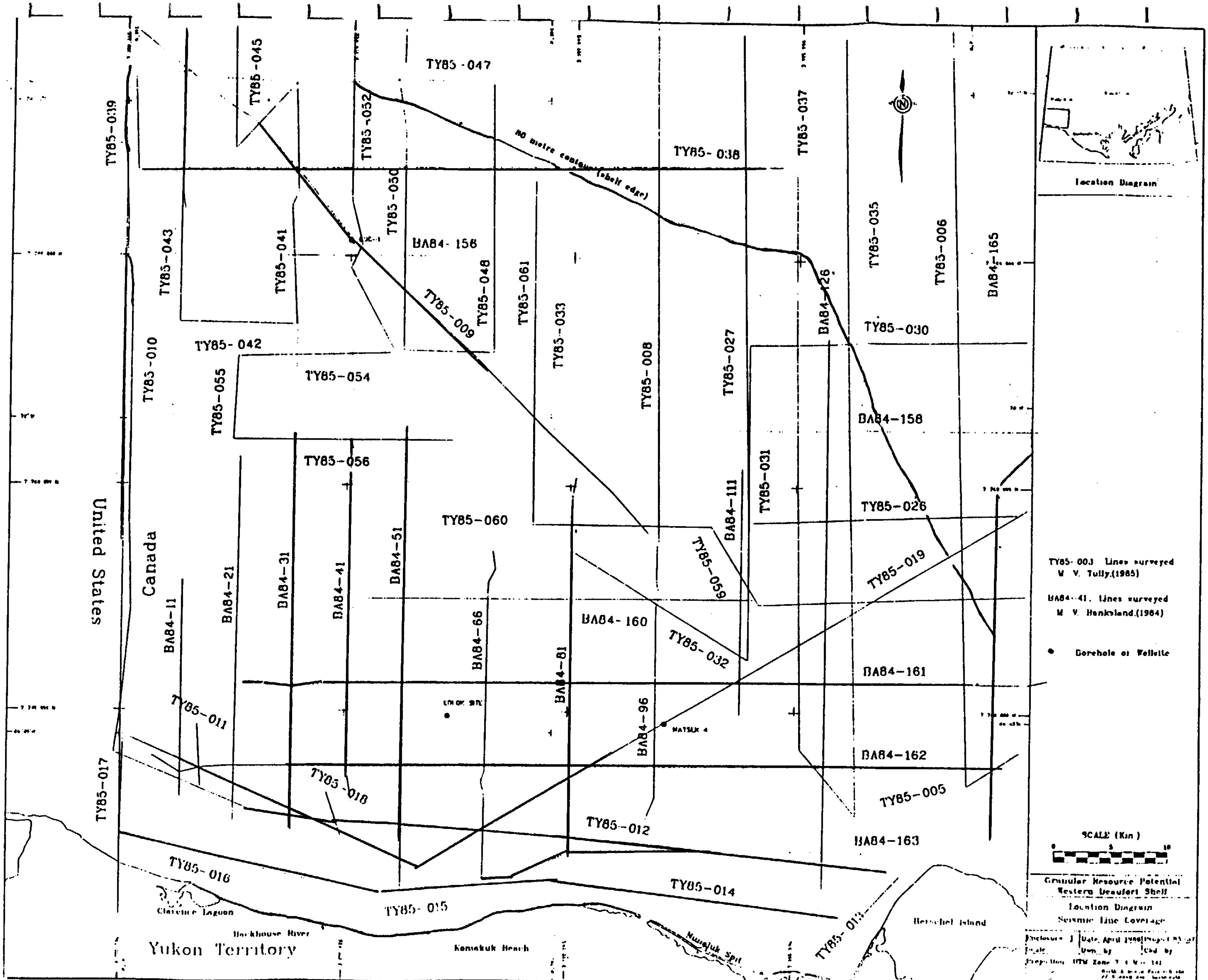
FIGURE 1

LOCATION DIAGRAM



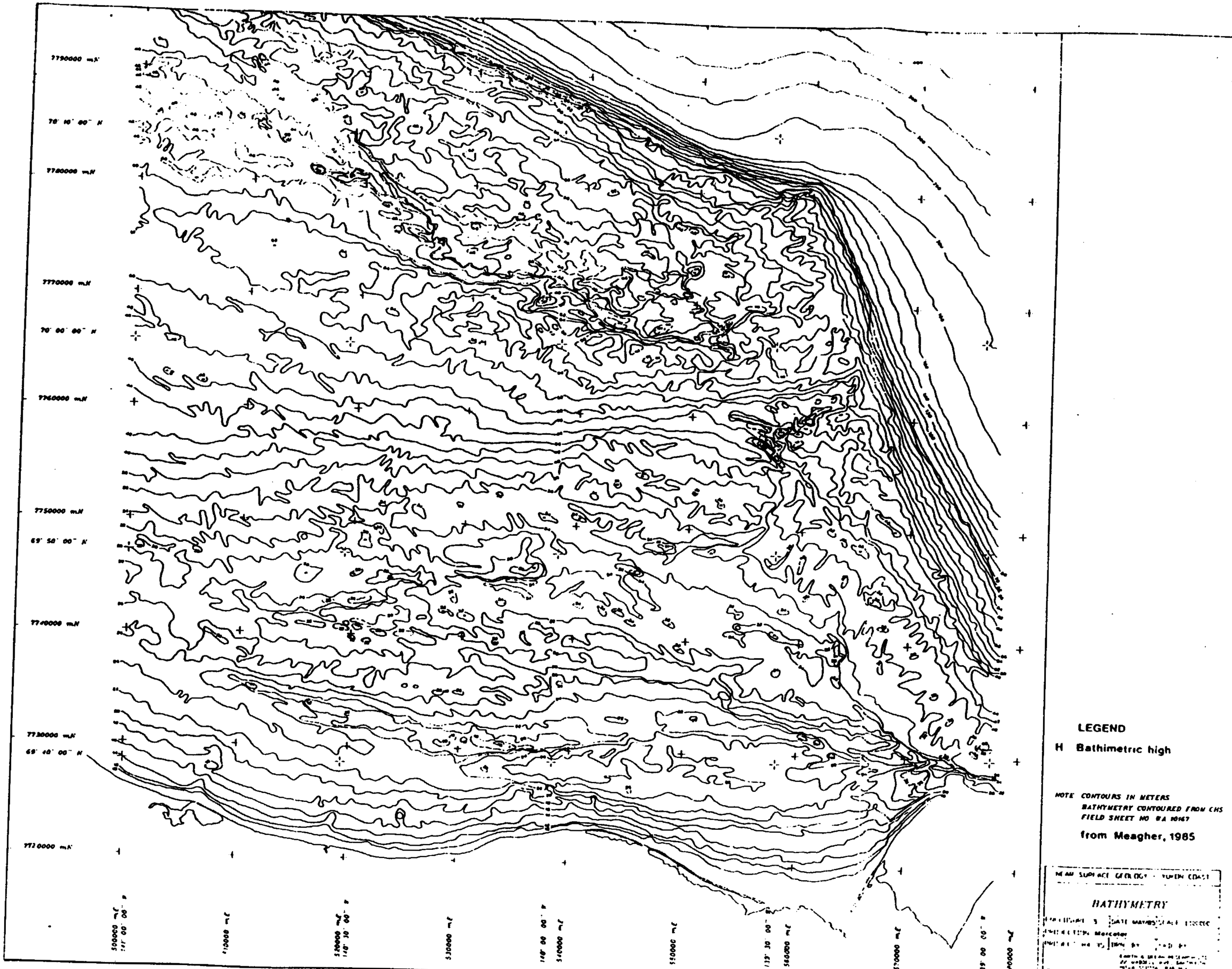
SAMPLE IDENTIFICATION AND DESCRIPTION

FIGURE 2



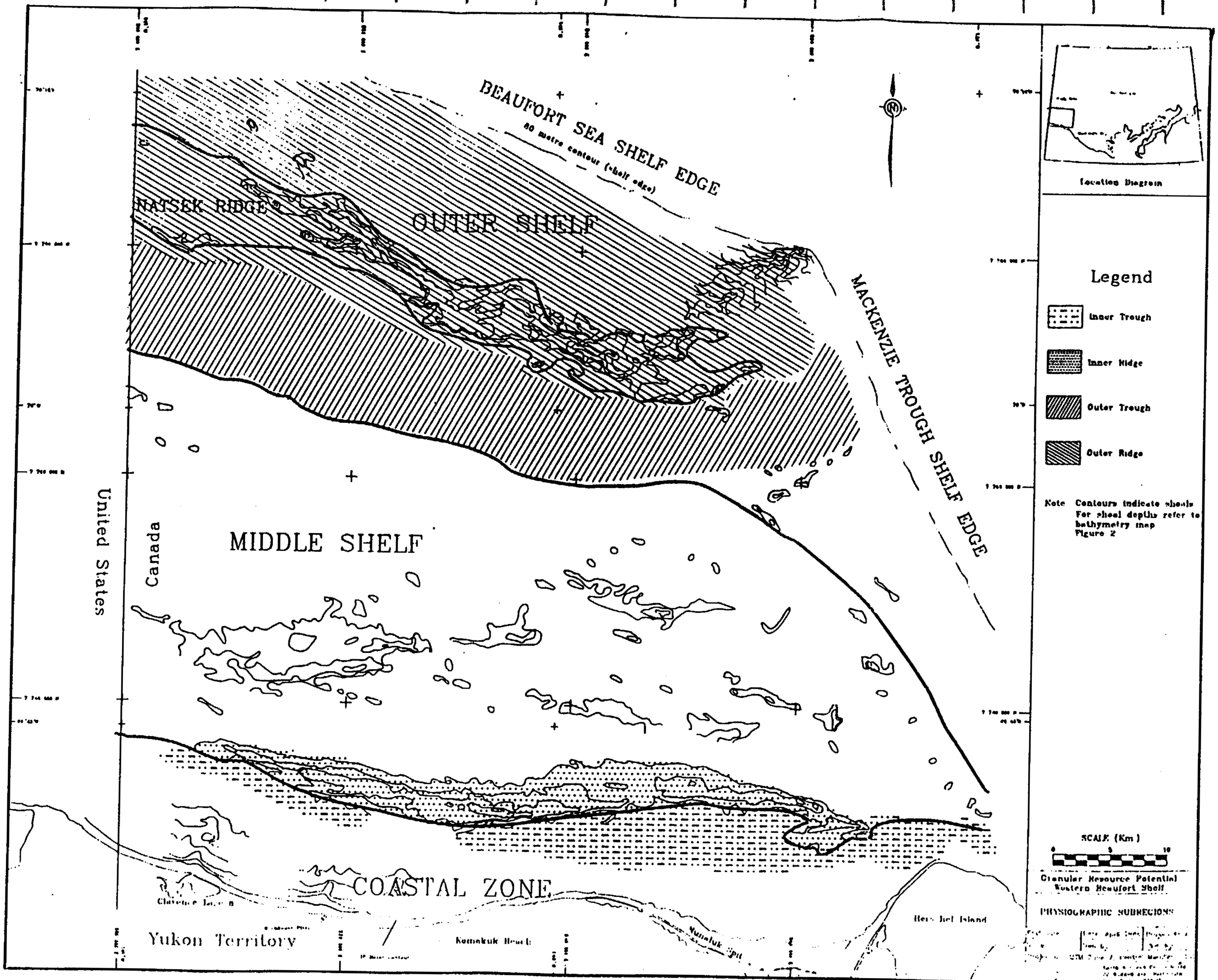
SEISMIC LINE COVERAGE

FIGURE 3



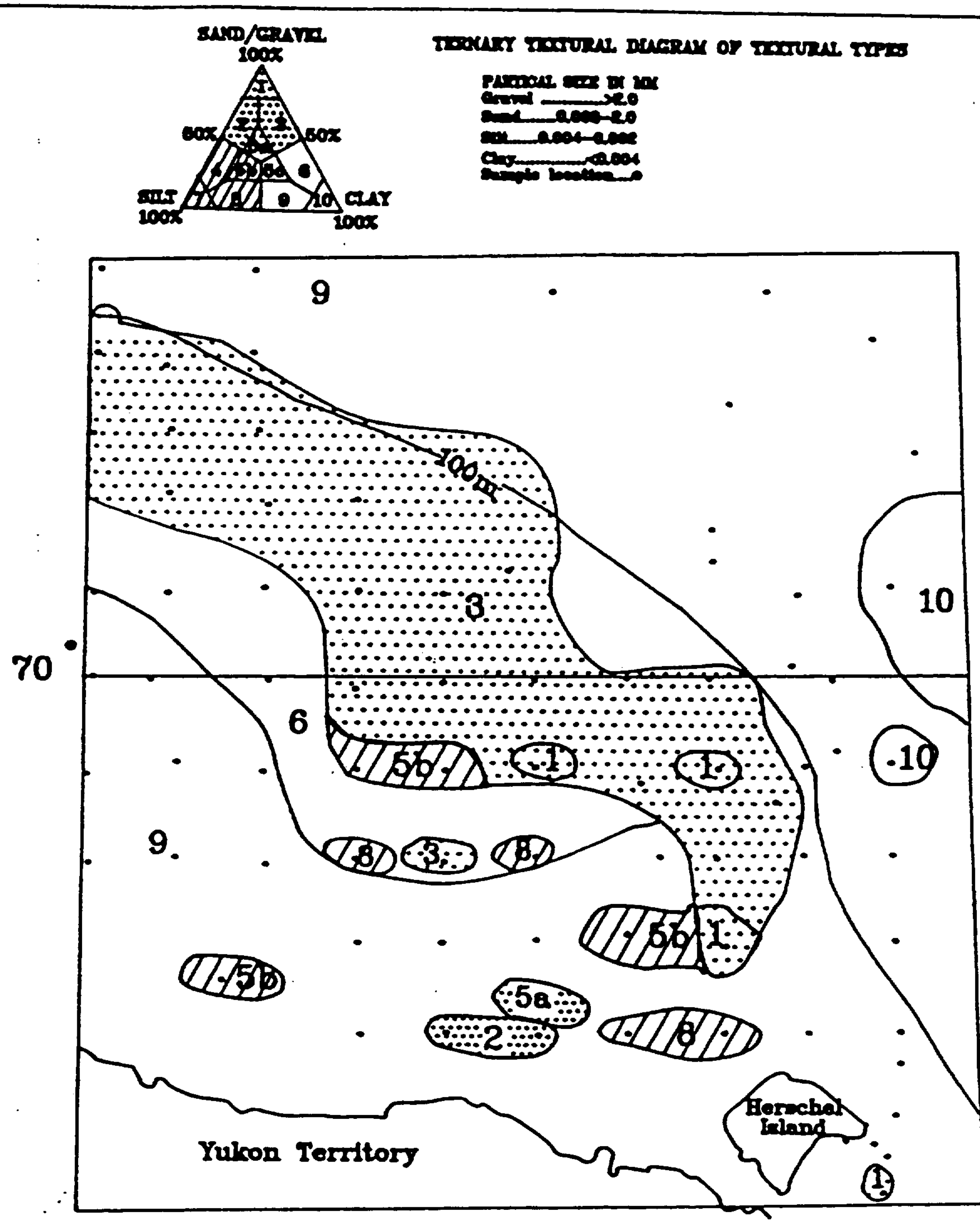
BATHYMETRIC CONTOURS

FIGURE: 1



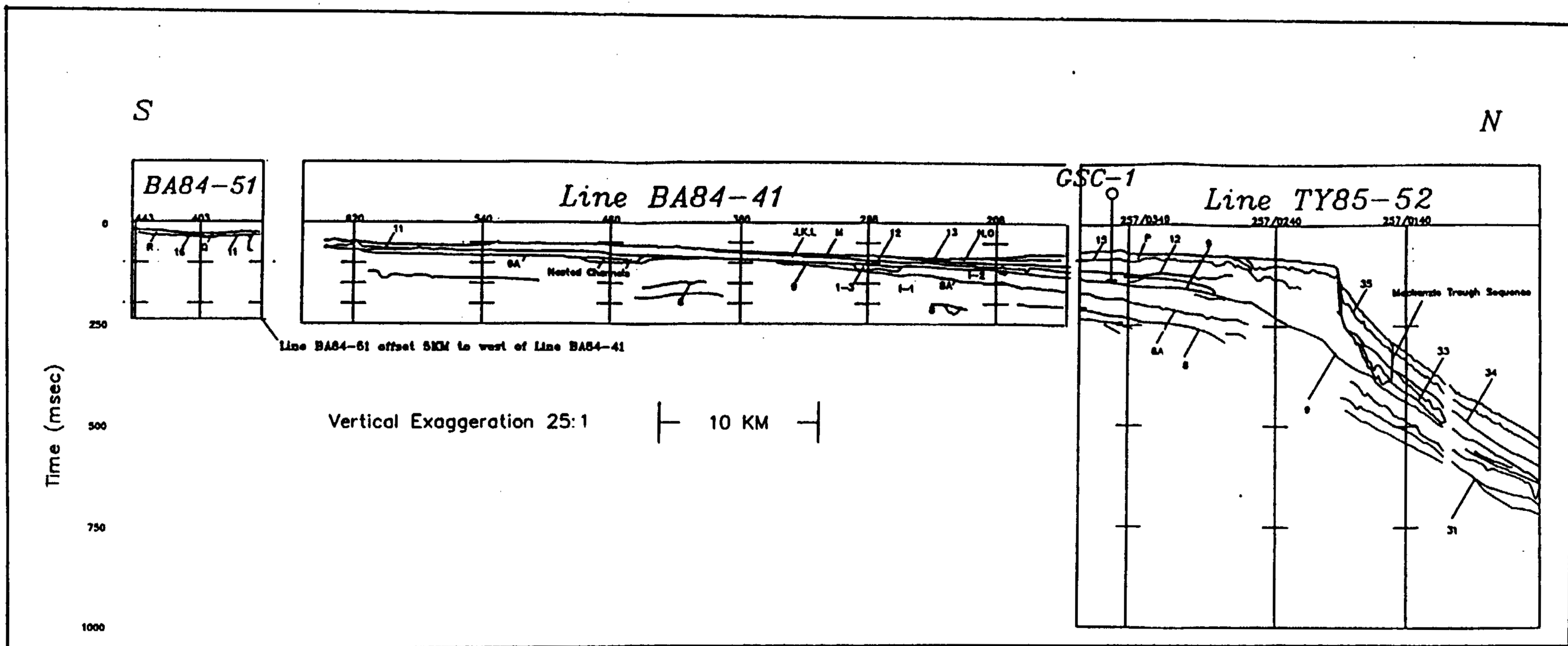
PHYSIOGRAPHIC SUBREGIONS

FIGURE 5



Distribution of bottom sediment types
(After Pelletier, 1985)

FIGURE 6



COMPOSITE LINE DRAWING ACROSS THE WESTERN BEAUFORT (YUKON) SHELF

FIGURE 7

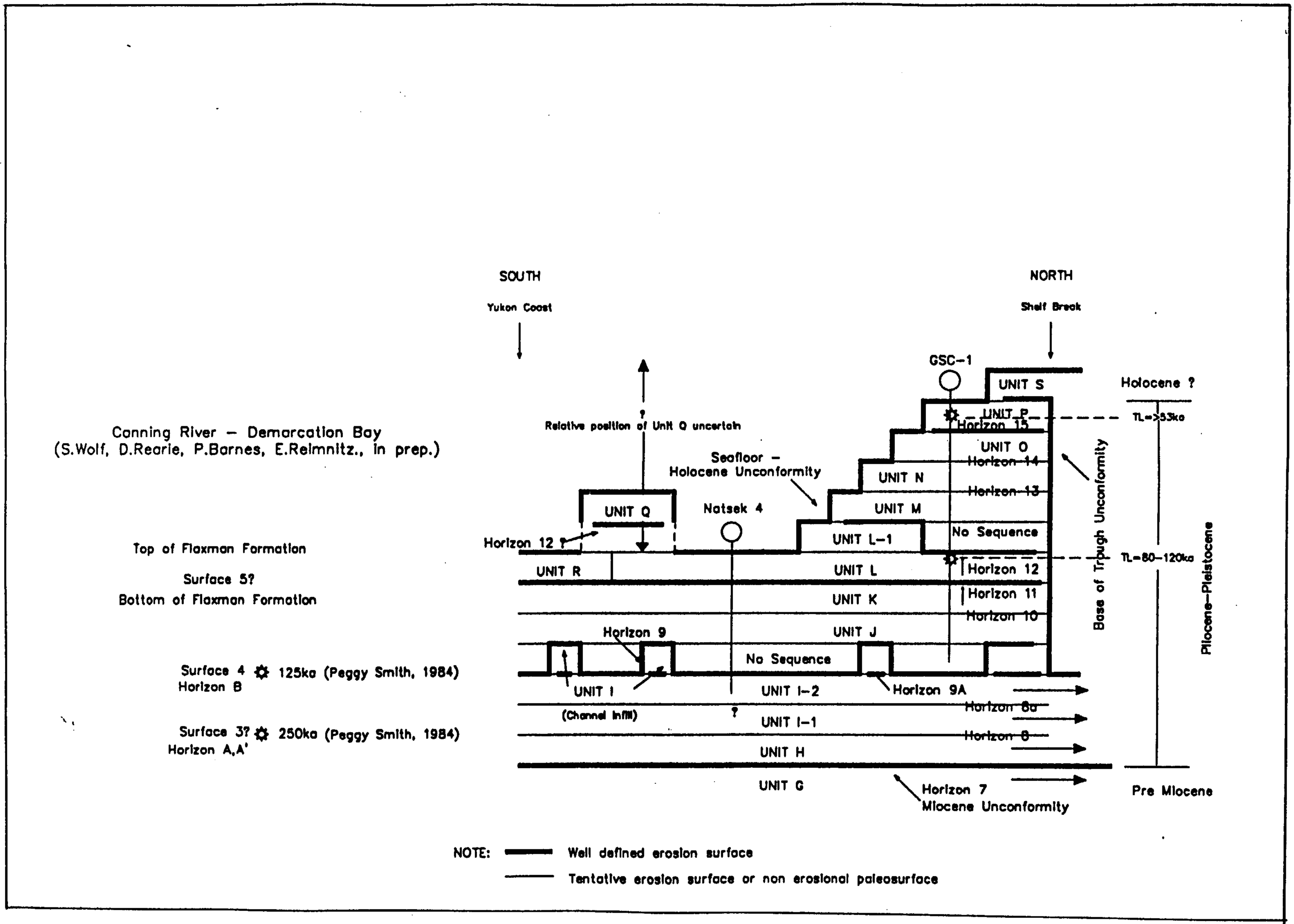
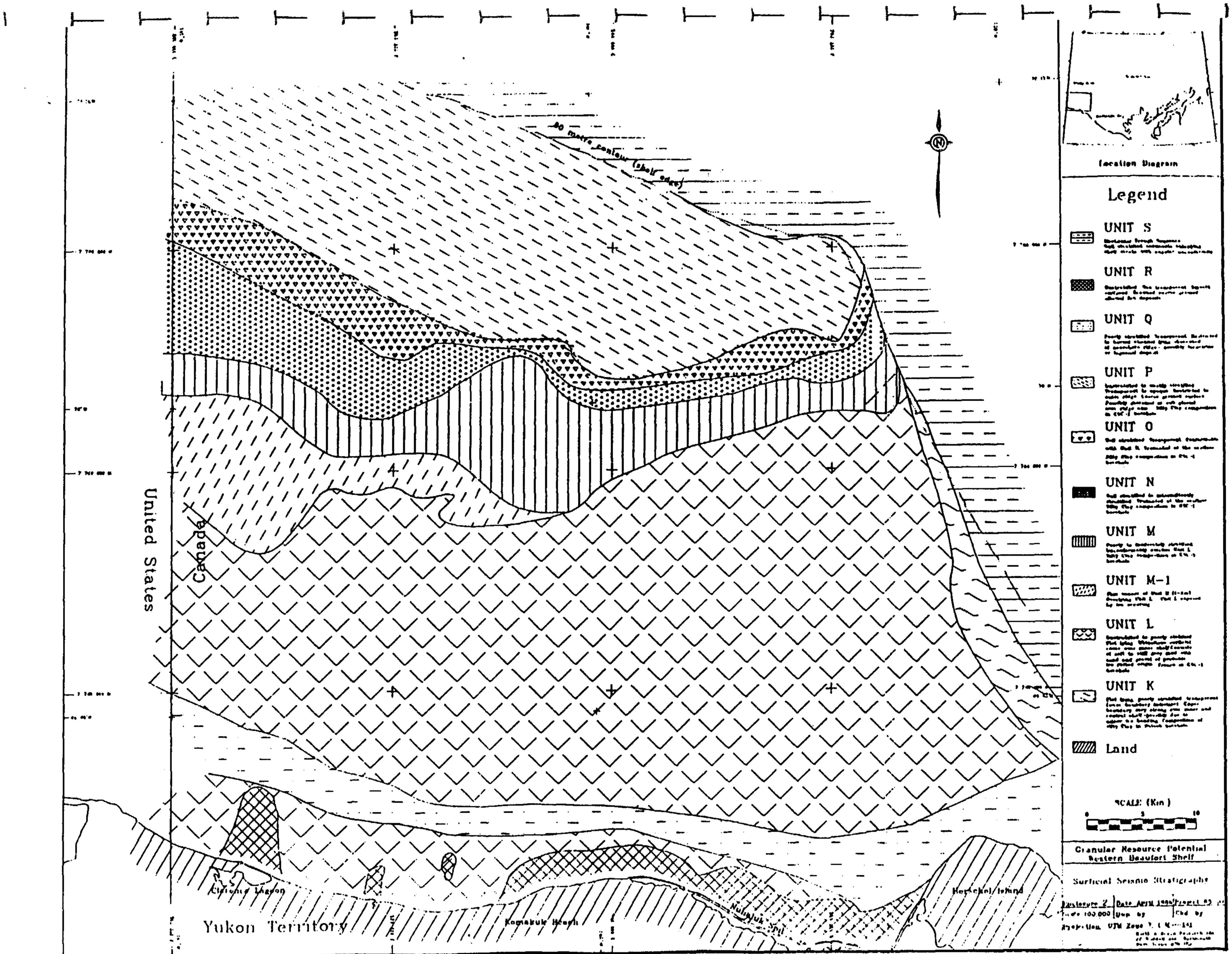
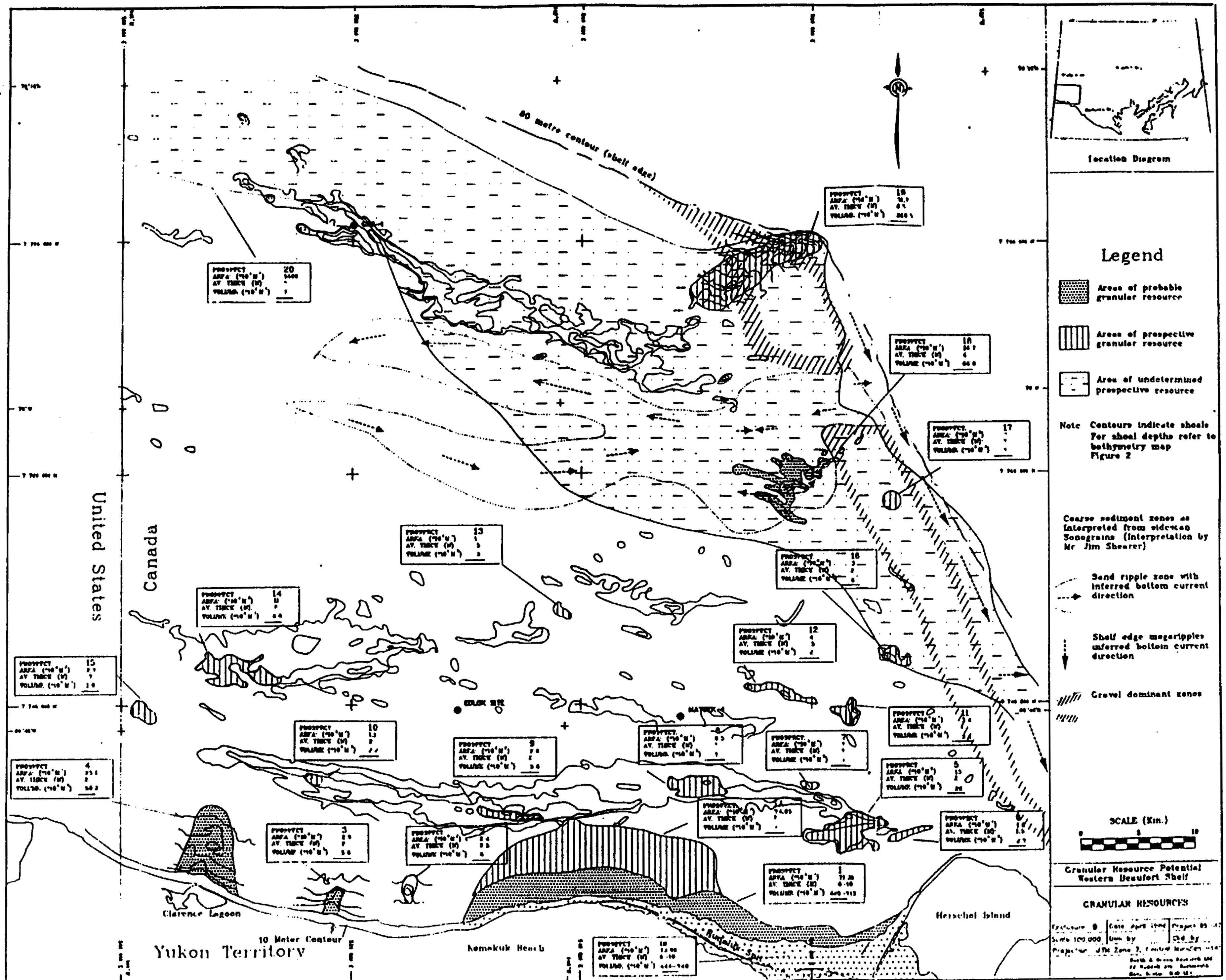


FIGURE 8 SEISMO-STRATIGRAPHIC RELATIONSHIPS AND AGES - WESTERN BEAUFORT (YUKON) SHELF



SURFICIAL SEISMO - STRATIGRAPHY

FIGURE 9



GRANULAR RESOURCES

FIGURE 10

Herschel Island Study
(NOGAP Project A4-01)

Presented By R. Quinn
Terra Surveys Limited
Sidney, British Columbia

1.0 Introduction

In 1984 and 1985, a series of studies were undertaken to locate and delineate potential areas for the future development of off-shore granular resources near Herschel Island, Yukon Territory. The work, carried out by M.J. O'Connor and Associates and EBA Engineering Consultants Ltd., was authorized by the Department of Indian and Northern Affairs and the studies were carried out in collaboration with the Geological Survey of Canada. In addition, the major petroleum operators assisted in the program by providing access to propriety data for incorporation in the synthesis of the geophysical and geotechnical data.

2.0 Geological Setting of the Area

The study area, shown in Figure 1, lies on the Natsek Plain, an area for which little sub-sea information was available prior to the DIAND Herschel Island study. Exposures on the Yukon Coastal Plain reveal sediments which are thought to pre-date the early Wisconsin glaciation. It has been suggested that these sediments were deposited during the non-glacial interval immediately preceding the early Wisconsin.

Sections of the pre-Wisconsin sediments exposed on Herschel Island reveal complex marine, deltaic, fluvial, lacustrine and even terrestrial depositional environments. It is thought that the early Wisconsin glaciation occurred greater than 40,000 years ago and may have been responsible for a major ice-thrusting event at Herschel Island. The Mackenzie Trough probably influenced the movement of the early Wisconsin ice sheet forming a lobe of ice to the northwest. The lobe is thought to have thrust sediments from Herschel Basin to form Herschel Island (Mackay, 1959).

Herschel Basin is separated from the Mackenzie Trough to the east by a submarine ridge or sill which joins Collinson Head to Kay Point. This ridge is thought to be an intact remnant of the original pre-Wisconsin marine sequence which escaped removal by the ice-thrusting event.

3.0 Methodology

A three-phase approach was carried out to determine the geological conditions:

- Marine geophysics to provide information on the nature of the soil conditions in the Herschel area.

- Marine geotechnical drilling to confirm the geological conditions interpreted from the seismic records and also to provide grain size distribution of the granular deposits.

- Synthesis of this data along with existing other regional data available.

3.1 Geophysical Program

The field data acquisition phase included coverage of the Herschel area by two vessels, the Norweta and the Banksland. The geophysical equipment included precision survey echo sounder, side scan sonar, sub-bottom profiler, boomer and air gun. Several hundred kilometres of data were collected over the study area between Collinson Head and Kay Point.

3.2 Geotechnical Program

The geotechnical field studies were carried out from the Arctic Kiggiak by EBA Engineering Consultants Ltd. Borehole locations were selected to determine the stratigraphy, both on Herschel Sill and Herschel Basin.

Four locations were investigated on the sill. At these locations, two boreholes were drilled and sampled to depths of 19.7 m and 5.7 m, while two probe holes were drilled to test the thickness of gravel at the other two locations. Surficial sediments at each of these locations were sampled using the grab dredge on the Arctic Kiggiak.

The additional two boreholes drilled within Herschel Basin were intended to test the possibility that some of the anomalous bathymetry within the basin may be due to glacially related granular resource deposits.

4.0 Sub-Sea Features in the Study Area & Their Granular Resource Potential

Four distinct sub-sea regions were identified and are shown in Figure 2. These included Herschel Basin, Herschel Sill, Yukon Coastal Shelf and the Babbage River Paleochannel.

4.1 Herschel Basin

The deepest water depths were found in Herschel Basin where the bottom of the basin is enclosed by the 50 m isobath and with water depths up to 80 m. The east side of the basin has pingo like features that rise steeply to within 25 m of the sea surface. Geotechnical and geophysical studies showed that the floor of the basin consists of approximately 40 m of laminated silty clay overlying sand, stiff clay and gravel. Ice lensing observed in the surficial clay suggests that the basin was drained and the bottom sediments exposed for some period of time in the past. Although extensive sand and gravel layers were noted in the sub-sea bottom sediments, the extreme water depths and the presence of a thick surficial clay unit preclude the development of any granular resources in Herschel Basin.

4.2 Herschel Sill

The precise sub-surface conditions which underlie the sill joining Collinson Head to Kay Point were difficult to resolve acoustically, but surface sampling, test dredging and several geotechnical boreholes proved useful in determining the surficial geology. For the most part, the sill is comprised of the same terrain units which may be found near Collinson Head and Kay Point. The eroded remnants of these mainly stiff, fine grained sediments are locally covered by modern sand and gravel shoals up to 7 m or more in thickness along the crest. South of Collinson Head, the bore holes and probe holes drilled on the crest of the sill showed granular thickness of up to about 3.5 m (Figure 3). The granular material was made up of sand and gravel containing sub-rounded to sub-angular particles. The coarse grained deposits are underlain by a stiff silty clay sequence.

Maximum water depths along the crest reach 17 m, but most of the sill is much shallower (4 - 12 m). In addition to ice scours, the presence of ripple marks along the crest of the sill as well as in other areas of the study such as the coastal shelf, provided indirect evidence regarding the nature of the sea floor and distribution of surficial granular resources. On the west side of the shoal north of Kay point, well developed ripple trains were evident. The ripple marks were also helpful in delineating both the nature of the surficial sediments and the lateral limits of individual soil types. In Figure 4, the boundary between the sandy and clayey soils at the seabed are clearly defined.

Discontinuous ice-bonding is common in the fine grained soils which constitute the regional sill sediments, but is not expected to occur in the modern sand and gravel shoals. Almost 17,000,000 m^3 of granular material suitable for engineering purposes are already known to be located in these shoals. The present information suggests that an additional 70,000,000 m^3 are probably available at the seabed and another 40,000,000 m^3 of material may also be located, if it can be proven that the glaciofluvial features noted near Kay Point also extend off-shore (Figure 5). Unfortunately, much of the granular resources on the sill are located in relatively shallow water depths, where conventional hopper trailer suction dredges may not be appropriate. Nevertheless, it is presumed that other technologies could be used for development if warranted by future granular resource requirements.

4.3 Yukon Coastal Shelf

The narrow coastal shelf which borders the north and west side of Herschel Basin was, like the Herschel Sill, difficult to map using high resolution seismic techniques because the water depths are shallow (less than 14 m) and the shelf is underlain by firm to stiff or dense materials which form part of the morainal, lacustrine or glaciofluvial sequences found along the coastline. Recent soft sediments appear to be absent in most areas, except near the basinward edge of the shelf. Geotechnical drilling conducted by Gulf Canada has verified that silty to gravelly sands may be found in certain areas near Stokes Point, but shallow ice-bonding was also present near the coastline. The most prospective area for future granular resource development appears to be located between Roland Bay and Catton Point, but no ground truth information is currently available in this area. Most of the present 9,750,000 m^3 of reserves on the shelf have been located by geotechnical boreholes. It is estimated that a total of 40,850,000 m^3 of sand and gravel may eventually be found on the shelf and along the coastline, if substantial additional drilling is conducted in the most prospective areas.

4.4 Babbage River Paleochannel

The drowned Babbage River Paleochannel does not appear to be generally prospective for development of seabed granular resources, especially in the deeper areas near Herschel Basin. The paleochannel may, however, contain some sand and gravel in the shallow waters near the Spring River or at greater depths below the seabed than were mapped during the present study. Total volume of these deposits is presently estimated to be only 3,500,000 m^3.

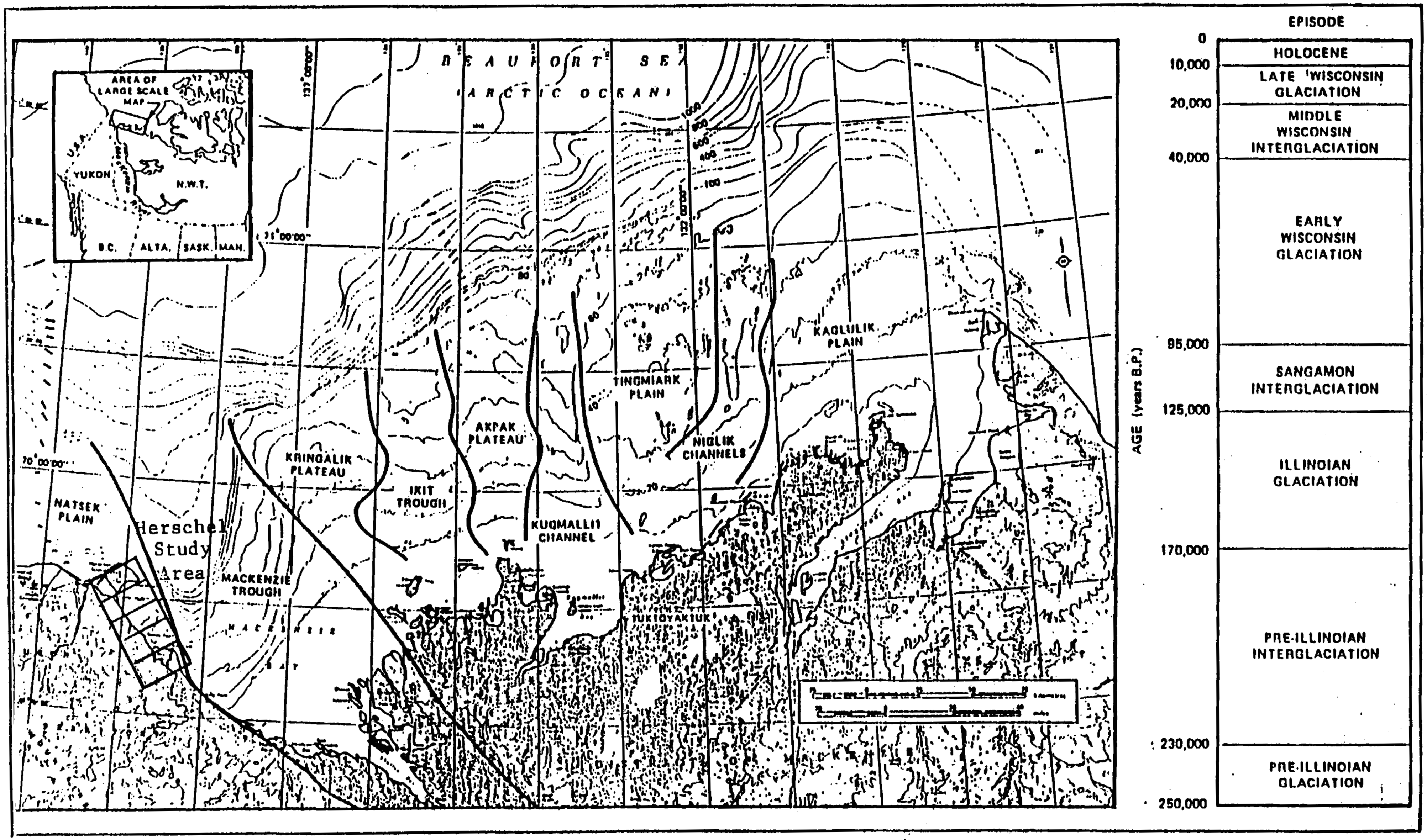
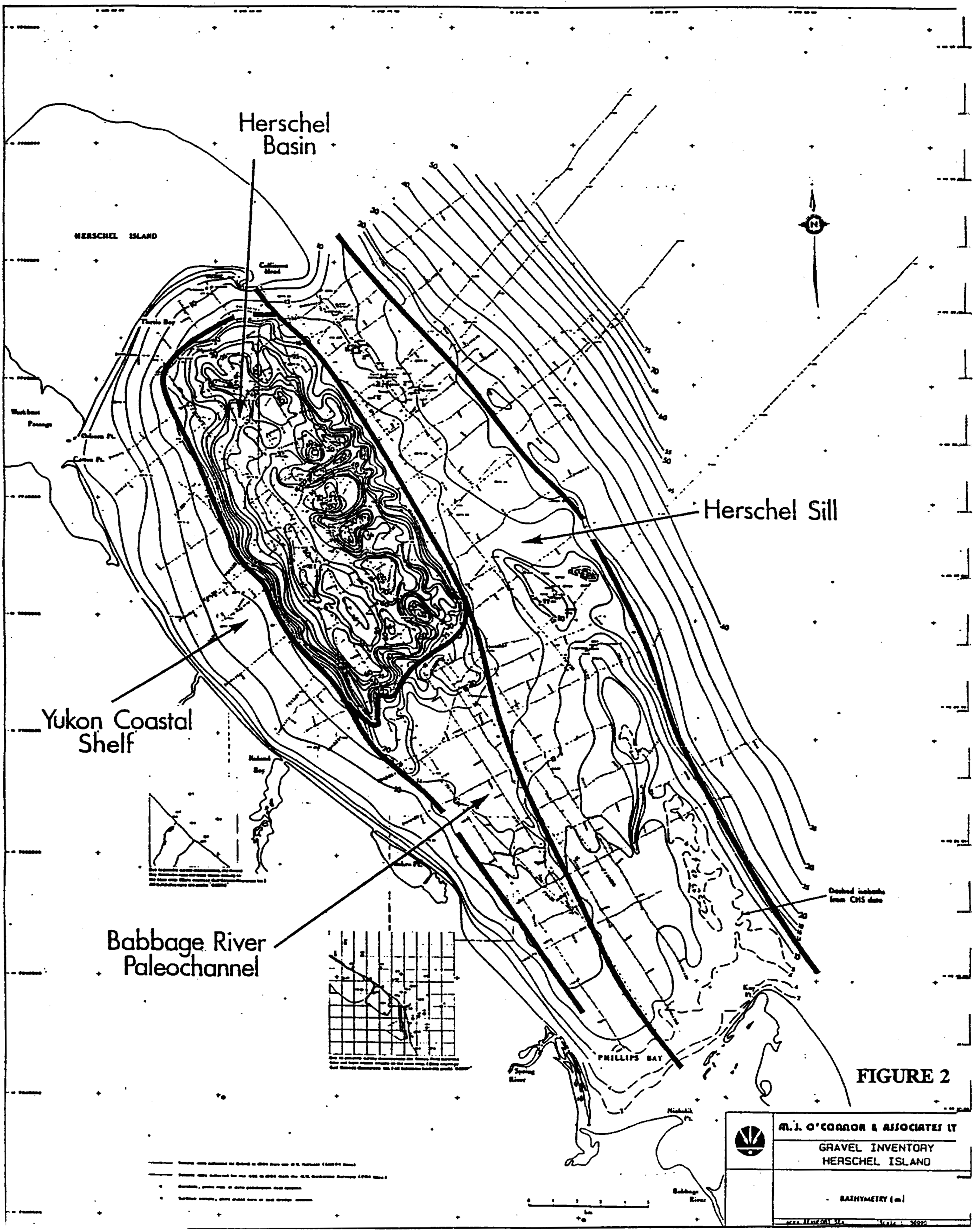
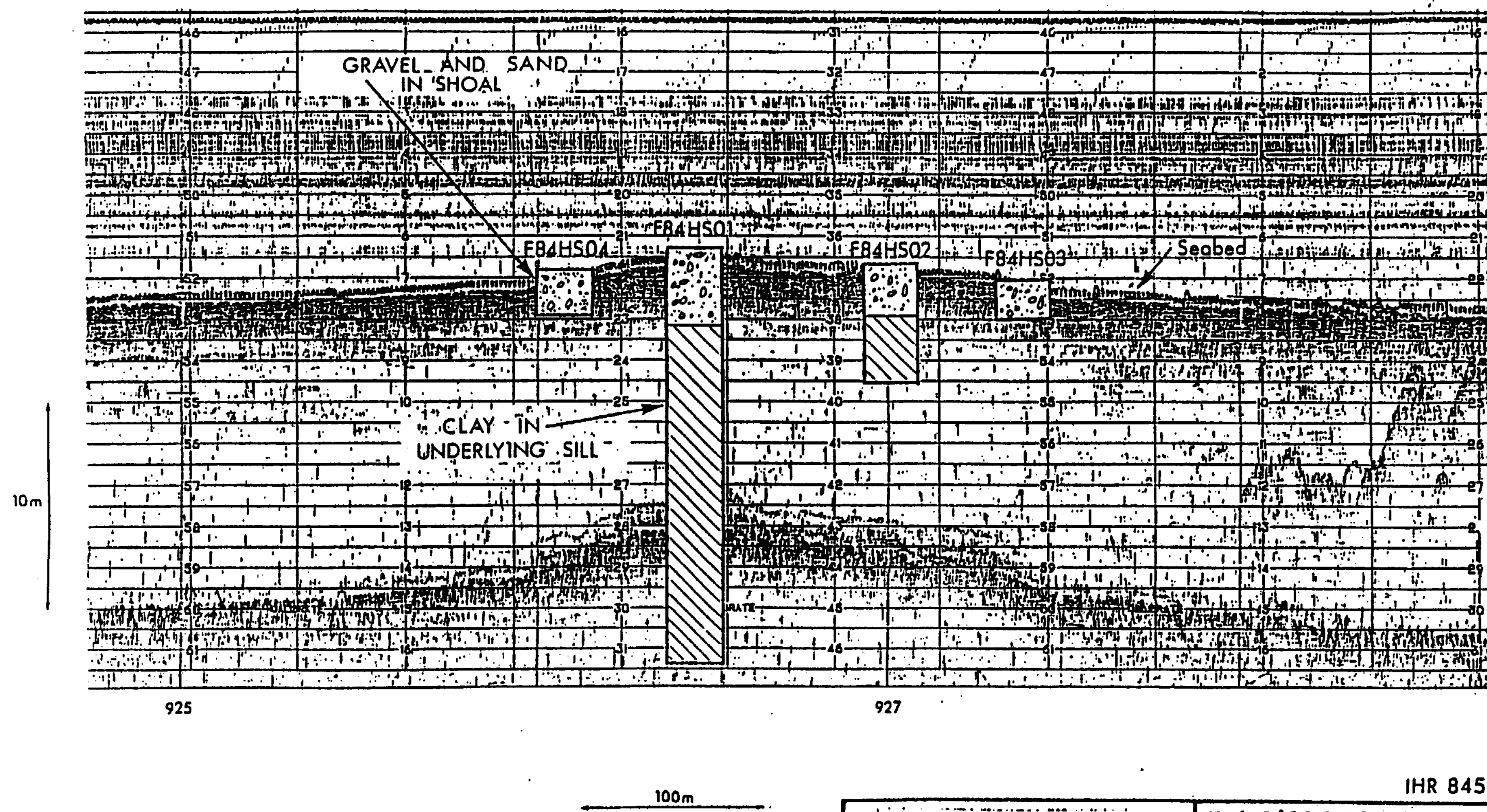


Figure 1. Herschel Island Study Area and Physiographic Regions of the Beaufort Sea with Geologic Time Scale.



Herschel Basin
HERSCHEL ISLAND
Herschel Sill
Yukon Coastal Shelf
Babbage River Paleochannel
PHILLIPS BAY
Dashed isobaths from CHS data
M. J. O'CONNOR & ASSOCIATES LT
GRAVEL INVENTORY
HERSCHEL ISLAND
BATHYMETRY (m)

FIGURE 2

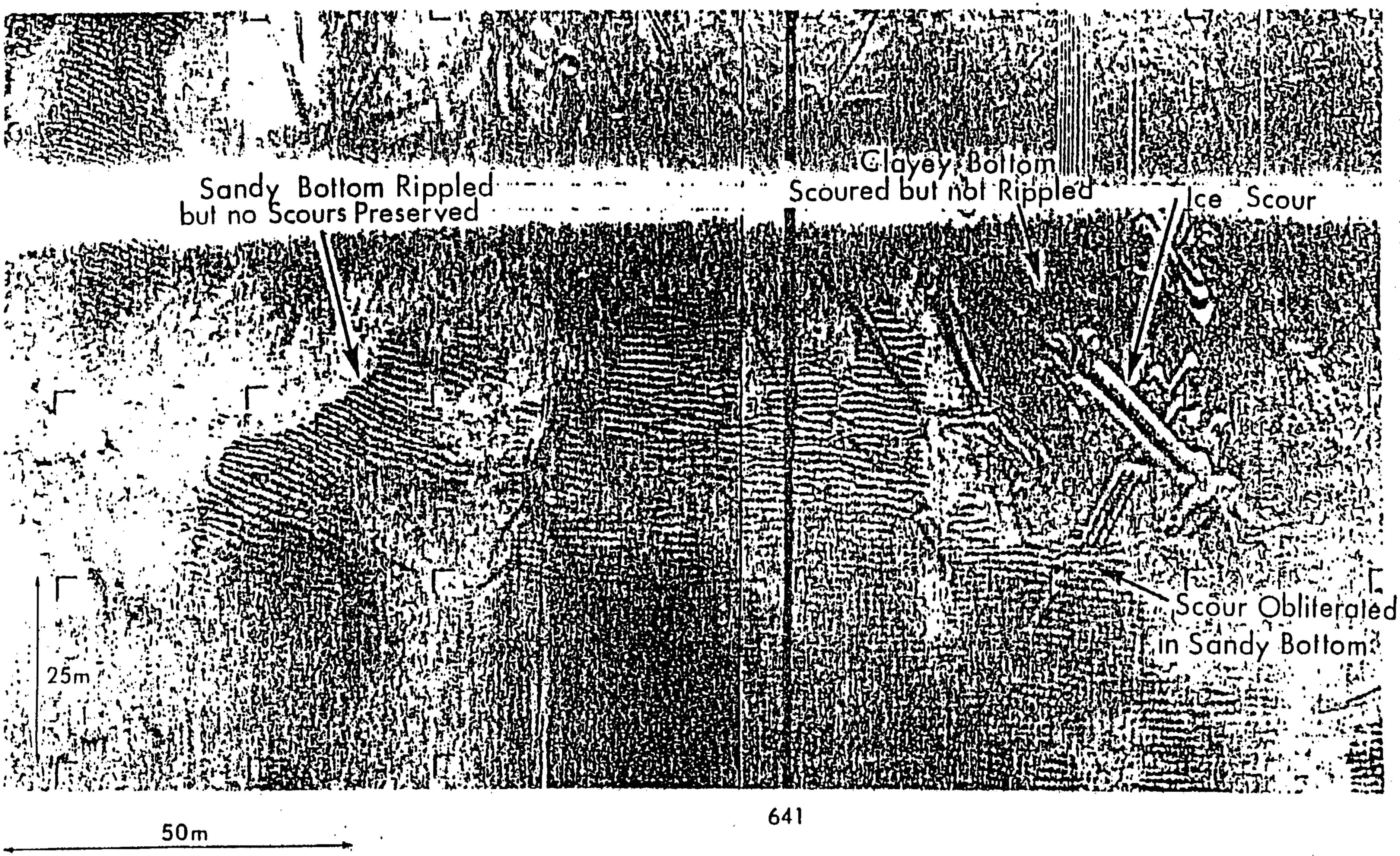


IHR 845

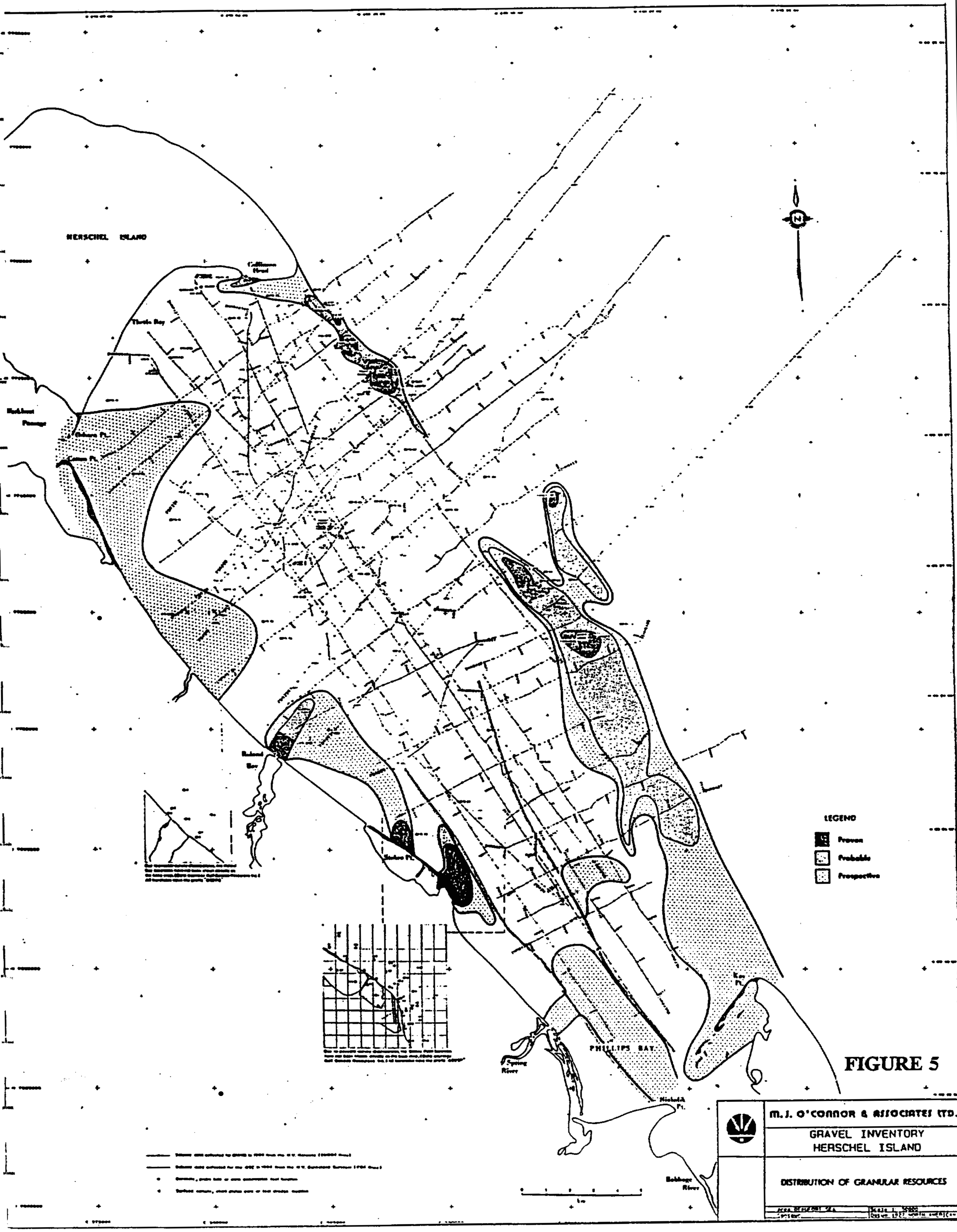
Stratigraphy of the Shoal South of Collinson Head	M. J. O'CONNOR & ASSOCIATES LTD	
	JOB No.: 110-260	DATE: 85/07/22
	DRAWN BY: MG	

STRATIGRAPHY OF THE SHOAL SOUTH OF COLLINSON HEAD

FIGURE 3



Ripple Marks Delineate Seabed Soil Type	M. J. O'CONNOR & ASSOCIATES LTD.	
	JOB No.: 10-260	DATE: 85/07/22
FIGURE 4	DRAWN BY: MG	



HERSCHEL ISLAND
Collinson Head
Thetis Bay
Osborn Pt.
Catton Pt.
Roland Bay
Stokes Pt.
PHILLIPS BAY
Spring River
Nicholls Pt.
Kay Pt.
Babbage River
LEGEND
Proven
Probable
Prospective
M. J. O'CONNOR & ASSOCIATES LTD.
GRAVEL INVENTORY
HERSCHEL ISLAND
DISTRIBUTION OF GRANULAR RESOURCES

FIGURE 5

Granular Resources of the Issigak Deposit
(NOGAP Project A4-06)

Presented by N.R. MacLeod
EBA Engineering Consultants Ltd.
Calgary, Alberta

1.0 Introduction

The Issigak site is unique in many ways. It is one of the few deposits with any significant portion of gravel in the Beaufort-Mackenzie region and is the only source of granular materials located between Herschel Island and the Akpak Plateau. For reference, Figure 1 shows the location of the deposit and the major physiographic zones nearby.

In late 1986 through March 1987, EBA Engineering Consultants Ltd. compiled and interpreted available data for the Issigak deposit (EBA, 1987). This work was conducted under funding provided by NOGAP Sub-Project A4-6, through Indian and Northern Affairs Canada. The primary purposes of the study were to interpret the geology of the deposit, and to quantify the remaining reserves. Those tasks were relatively easy. The hard work was in finding the data, much of which was missing, and resolving inconsistencies between overlapping data sets.

2.0 History of Site Evaluation

The first site work on shallow sediments in this area was done in late winter 1974. More work was done in winter 1975. Both programs were conducted through the ice at about the limit of conventional land based equipment. Although we encountered minor gravel and other geologically unique sediments during those programs, we didn't "discover" the Issigak borrow deposit. The credit for the discovery should go to Dome Petroleum which began gravel exploration in the area in the summer of 1980. They were searching for construction materials for work at the Tarsuit N-44 site.

Between 1974 and summer 1986, there were 26 various programs or operations at Issigak. Included in that were nine geotechnical sampling programs, six seismic mapping programs, eight dredging operations, and three bathymetric mapping exercises. Prior to 1986, almost 3.5 million cu.m. of granular material were reported to have been removed from Issigak during four of the dredging operations. In addition, there were four other dredging programs for which the quantity of material removed could not be determined.

3.0 Data Reliability

The problem with too much data is that it has to be compared to look for inconsistencies. At Issigak, there were 199 boreholes, several bathymetric surveys and bathymetric data collected during seismic programs. The correlation between various data sets was found to be very poor. This has serious implications for many other sites because of the scale of inaccuracies implied. For example:

- The difference between water depth interpreted from borehole soundings and bathymetric surveys was greater than 1.0 m for 25% of boreholes. That is a big error for a site in only about 9.0 m of water.

- The difference between various sets of bathymetric mapping was not much better. Datum differences of 0.5 to 1.0 m are common between data sets.

- Where two boreholes were located nearby, the differences in sub-surface interpretation was frequently enough to imply that one of them must be wrong. For nine pairs of holes with an average distance apart of 27 m (maximum 40 m), the average difference in granular material thickness was greater than 0.4 m (max. 0.8 m) and the average difference in water depth was 0.4 m (max. 0.8 m). These are significant differences for a deposit with an average thickness of less than 1.5 m.

4.0 Physical Description

Figure 2 shows the size of the deposit in comparison to northwest of Calgary. It is presented this way because it is easy to underestimate the aerial extent of Issigak on a map without reference to nearby land features. The deposit is almost 11 km long and up to 1500 m wide.

In section, the deposit is a thin veneer which averages less than 1.5 m thick. Issigak appears as a low ridge or series of small knobs on most bathymetric maps because of the overall flatness of the coastal sediments. Figure 3 shows the maximum section through the ridge. Drawings with high vertical exaggeration serve to create the impression of a ridge. Figure 4 shows the ridge at a vertical exaggeration of only 10x. This is a much better section to picture when considering the morphology of the deposit.

Detailed bathymetry, compiled in Figure 5, shows four or five pods of higher relief. The relative importance of initial deposition and subsequent erosion in producing this relief is difficult to establish. These areas of high relief, however, are generally related to the thickness of granular resources. They are also related to the distribution of boreholes, because most were located on areas of higher relief. Figure 6 shows the distribution of boreholes.

Our understanding of the thickness of the deposit is somewhat skewed because the boreholes have been concentrated in areas of highest relief. Based on 162 boreholes which were mostly in the thicker parts of the deposit, the average thickness of the Issigak granular resources is 1.44 m. Overall the average thickness is less.

5.0 Stratigraphic Characteristics

There are enough boreholes in the deposit to develop a reasonably complex facies model of it. Table 1 shows the strata sequence that has been interpreted. It was not practical to try and indicate the thickness of these 12 units and sub-units for such a relatively thin deposit. In fact, the total strata sequence never appears in any borehole, but each unit appears in more than one borehole. Figure 7 shows what might be a typical section, if there is one.

Cobbles and boulders are easily missed by boreholes unless they are in a relatively high concentration. From dredging quality control work, there are reports that some dredge hopper loads contained up to 10% cobbles and boulders. Cobbles up to 130 mm were common and boulders up to 500 mm were observed. Figure 6 indicates the frequency of boreholes encountering cobbles in the deposit and Figure 8 indicates the distribution of coarse material on the seabed.

The relative distribution of sand and gravel within the deposit also was investigated. Based on gradation data provided by the borehole logs an interpretation of the sand to gravel ratio was made for each borehole. By averaging the ratios so derived for eight subdivision of the deposit shown on Figure 9, a trend to a decrease in the gravel fraction (ie. to finer material) from southwest to northeast was identified. The frequency for cobbles, indicated on Figure 6, seems to be greatest in the southwest but relatively uniform along the north arm of the deposit.

6.0 Quantity Determination

It is not possible to determine the quantity of granular material that was originally in the Issigak deposit. As indicated previously, in excess of 3.5 million cubic metres of material had been removed prior to 1986. For at least four other dredging programs, the quantity of material removed was unknown.

Bathymetric data collected for Esso in 1984 and 176 boreholes obtained for Esso in 1983 (EBA, 1983) provide the basis for understanding the quantity of granular material on site, although 1.5 million m^3 of granular resources were removed between those two times.

It was concluded that at the end of 1986, reserves of granular material on site were as follows.

- Proven Reserves 3.3 million cubic metres
- Probable Reserves 5.1 million cubic metres
- Prospective Reserves 5.8 million cubic metres

7.0 Geologic Age

The Issigak deposit was interpreted in this NOGAP study to be of early Holocene age. That means the deposits are non-glacial and likely non-marine. The basis of this interpretation is the correlation of regional unconformities on several regional seismic lines by Guy Fortin (1986) and some biostratigraphic work done by Elliot Burden (1986).

Burden's work on samples from the Tarsiut N-44 site identified three unconformities. The earliest lies below non-marine sediments that Hill (1985) dated at 27,000 years. The second occurs above non-marine sediments which have an age of about 14,600 and overlie prograding late-Wisconsinian deltaic sediments. Above the second unconformity are early Holocene shallow deltaic sediments which were dated between 9,500 and 6,800 years. The third unconformity lies between those and pro-deltaic (marine) late-Holocene sediments that are less than 6,800 years old. This unconformity (U/C3) is the trace of the last marine transgression.

The process by which the three unconformities at Tarsiut N-44 can be traced to Issigak is a little complex. The first correlation was one of stratigraphic similarity between Tarsiut A-25 and N-44. These two site are a little less than 6 km apart. Table 2 shows this correlation. At Tarsiut A-25, Unconformity U/C2 is about 16 m below seabed (bsb).

The next step in the correlation was Fortin's interpretation of a seismic line extending southward from Tarsiut A-25 and passing about 12 km west of Issigak. Figure 10 shows that section. The relatively unvarying depth of Unconformities U/C1 and U/C2 suggest that Wisconsinian sediments are deeply buried at Issigak. Unconformity U/C2 was interpreted to be 10 to 15 m bsb near Issigak.

The third correlation, shown on Figure 11, traces Unconformities U/C2 and U/C3 from Esso's Omat and Kaubvik sites past Issigak at a distance of about 2300 m to the north and further west to a point about 11 km west of Issigak. Unconformity U/C2 is about 10 m below seabed and U/C3 is about 4 m bsb where they pass Issigak.

The fourth tie-in to this correlation is based on stratigraphic correlation of a series of boreholes between Esso's Kadluk 0-07 site and Issigak. This profile, which location is shown on Figure 12, crosses the Omat seismic line and ties the regional seismic data to Issigak.

The stratigraphic features that have been correlated along this section are interesting. There is a zone which begins at the depth of Unconformity U/C2 on the Omat line and can be seen in five of the boreholes between Issigak and the Omat line. It has the features of partially desiccated terrain such as blocky texture and salt encrusted fissures. Overlying that is a silty clay strata containing occasional fine pebbles (drop stones?). This horizon appears to correlate with evidence of unconformable strata changes at 8 to 9 m bsb under the Issigak deposit and at about 8 m bsb inshore of Issigak. Figure 13, shows the interpreted section.

Late Holocene (recent marine) sediments appear to pinch out between the Kadluk site and Issigak. In some boreholes the dropstone clay strata is exposed on the seabed and in others it underlies a thin strata of recent sediments. This interpretation, based mostly on borehole data, could be confirmed with seismic records which could not be found for the study.

In conclusion, it appears that the Issigak deposits pre-date the last marine transgression, which Hill (1985) suggests would be about 2500 years ago. Furthermore they are situated on top of approximately 6 m of early Holocene deltaic sediments which correlate to those Burden dated at between 9500 and 6800 years.

8.0 Sediment Geology

The surface on which the early Holocene deltaic sediments were deposited may have been well above seabed. It is likely that shell fragments, finely laminated clays, and interbedded sands with organic rich strata must be fluvial or lacustrine in origin. Furthermore, it would take a relatively large fluvial channel to move over 9 million m^3 of sand and gravel with cobbles and boulders up to 500 mm. Therefore it is puzzling that such a channel has not been identified on any seismic section or in any borehole.

It also is difficult to conceive of a source for the granular material that is far upslope of the present deposit. The fluvial erosion of a barrier island, like Pelly Island, has been suggested as a possible source for coarse material; however, there is no evidence, as yet, of a rise to the seabed of Unconformity U/C1 and the older, coarser sediments. The question of source area and details of the transport system have not been resolved, as yet.

9.0 References

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Fortin, G. (1986). 'A Preliminary report on the Issigak Deposit'. An interim project report submitted to EBA Engineering Consultants Ltd.

Hill, P.R., Mudie, P.J., Moran, K. and Blasco, S.M. (1985). 'A Sea Level Curve for the Canadian Beaufort Shelf'. Canadian Journal of Earth Sciences Vol. 22, No. 10, pp. 1383-1393.

Table 1
Stratigraphy of the Issigak Deposit

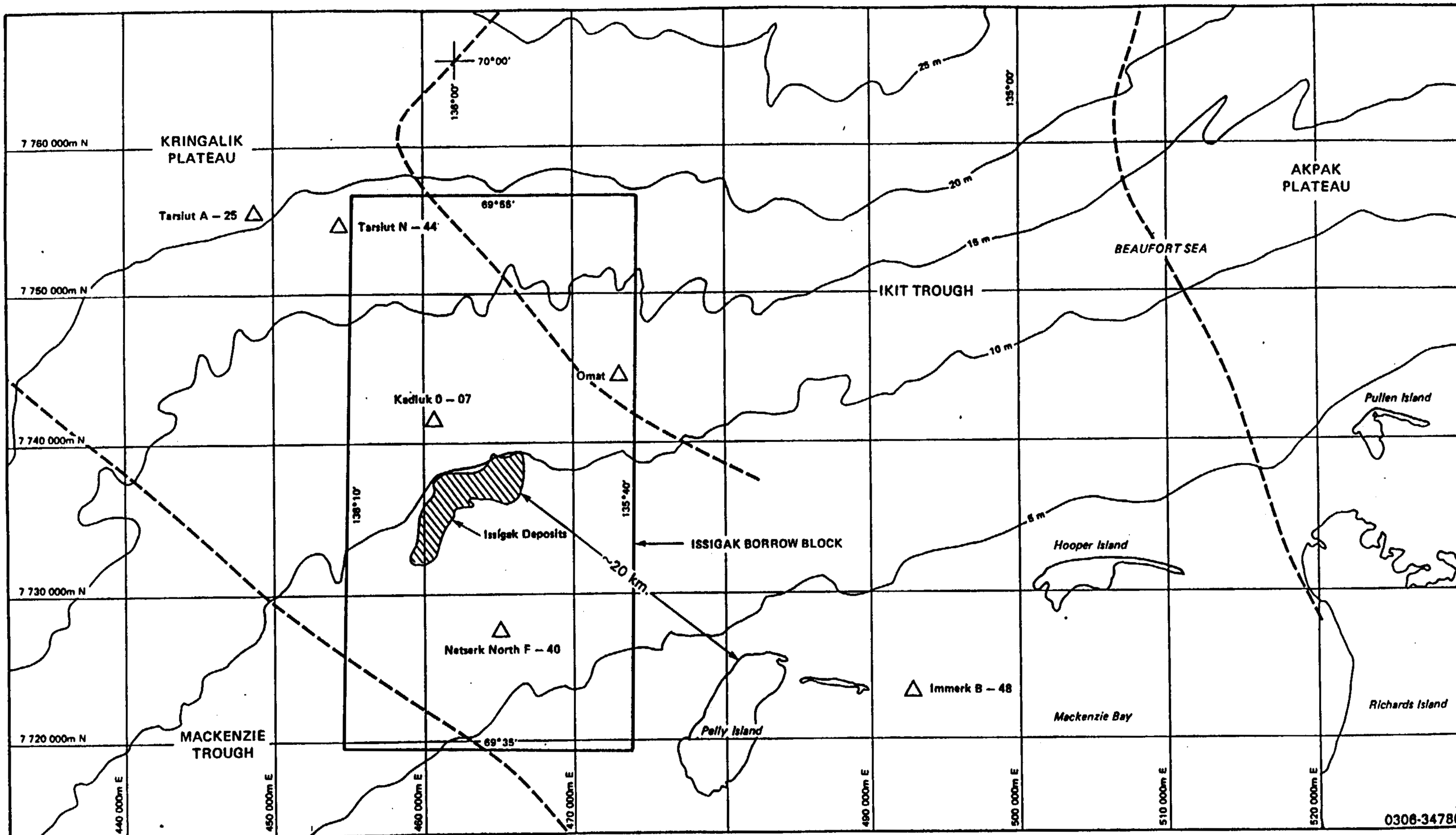
Unit Name	General Description
1A - Overburden Clay	• Soft silty clay of Holocene age. • Thin, irregular veneer, generally absent over main prospect.
1B - Interbedded Clay & Gravel	• Stratified sediments of Holocene? • Clay and gravel washed landward of main prospect.
2A - Upper Sand	• Clean to silty sand, thin but widespread on flanks of main prospect.
2B - Main Gravel	• Ranges from gravel-sand ($2B_1$) to gravelly sand ($2B_2$), coarser on top and may contain cobbles.
2C - Underlying Sand	• Stratified clean, uniformly graded sand ($2C_1$) over silty fine sand ($2C_2$), may contain shell fragments and organic-rich zones.
2D - Clay Interbed	• Silty clay up to 1.2 m thick occurring in at least three areas of main prospect.
2E - Lower Gravel & Sand	• Found below Unit 2D, commonly a gravel strata ($2E_1$) overlying a Sand strata ($2E_2$): $2E_1$ - very similar to 2B. $2E_2$ - very similar to $2C_2$.
3 - Underlying Clay	• Below all granular sediments are: 3A - Interbedded laminae of clay or sand. 3B - Organic-rich silt or clay. 3C - Silty clay.

Table 2
Regional Stratigraphic Comparison

Tarsiut A-25 (from McClellard, 1978)		Tarsiut N-44 (by P. Hill in Burden 1986)		Burden's (1986) N-44 Interpretation			Kadluk H-08 (from Hardy, 1983)		Kadluk 0-07 (from Hardy, 1983)	
7 756 500 m N 448 200 m E		7 755 000 m N 454 000 m E		UTM CO-ORDINATES			7 742 360 m N 461 300 m E		7 741 500 m N 400 600 m E	
DEPTH (m) (bsb)	DESCRIPTION	DEPTH (m) (bsb)	DESCRIPTION	UNIT	DEPOSITIONAL ENVIRONMENTAL	INTERPRETED AGE	DEPTH (m) (bsb)	DESCRIPTION	DEPTH (m) (bsb)	DESCRIPTION
0-3	Olive grey soft to firm clay with shell fragments	0-6	Grey bioturbated clay with shell fragments	A	Prodelta Becoming Marine Unconformity (U/C_3)	Present $\underline{\leq 6\,800}$ 7 500	0-3	Soft silty clay	0-2.5	Soft silty clay, trace of gravel
3-16	Dark grey silty clay with silt partings to lenses stiff to very stiff	6-15	Dark grey bioturbated silty clay with silt lenses and dessicated horizons	B	Delta Unconformity (U/C_3)	$\underline{9\,500}$ 14 600	3-13	Stiff silty clay	2.5-13	Stiff silty clay, laminated, some sand layers near top, trace of gravel
16-22	Dark grey silty fine sand with some gravel	15-21	Laminated/ lenticular graded silty clay (top) to graded sand and clay (bottom)	C	Becoming Non-Marine	17 000	13-26	Compact silt	13-17	Silt sandy to trace of sand
22-34	Olive grey silty clay with silt partings grading down to clayey silt with clay partings	21-36	Laminated dark grey silty clay (gradational transition)	D	Prograding Delta				17-34	Interbedded silty clay and clayey to sandy silt

Table 2 (Continued)

Tarsuit A-25 (from McClelland, 1978)	Tarsuit N-44 by P. Hill Burden 1986)	Burden (1986) Tarsiut N-44 Interpretation	Kadluk H-08 (from Hardy, 1983)	Kadluk 0-07 (from Hardy, 1983)
34-60 Olive grey clay with silty partings and silty layers	(gradational transition) 36-56 Laminated silty clay	E Prograding Delta	26-70 Very stiff silty clay	34-61 Very stiff laminated silty clay with occasional silt pockets
	56-66 Homogeneous bioturbated silty clay with forams	F 18 000		
60-86 Olive grey clay with organic and sandy pockets and some shell fragments 86-94 Olive grey clayey silt with some wood fragments 94-121 Grey clay with silt lenses and partings some wood fragments 121-122 Silty fine sand End of borehole	66-129 Thick bedded, laminated clay with some sand beds and organic debris	Prodelta to Marine G Marine Transgression	70-76 Dense fine sand 76-100 Stiff clay 100-113 Stiff silty clay 113-131 Stiff silty clay. End of Borehole	61-93 Dense fine sand, occasional shell fragments and thin silt and clay layers. End of Borehole
	129 Dated Peat Horizon 130-166 Laminated silt and clay. End of Borehole	Non-Marine 27 000 H Rapidly Prograding Delta		



EBA Engineering Consultants Ltd.

PHYSIOGRAPHIC REGIONS

FIGURE 1

(after O'Conner, 1982)

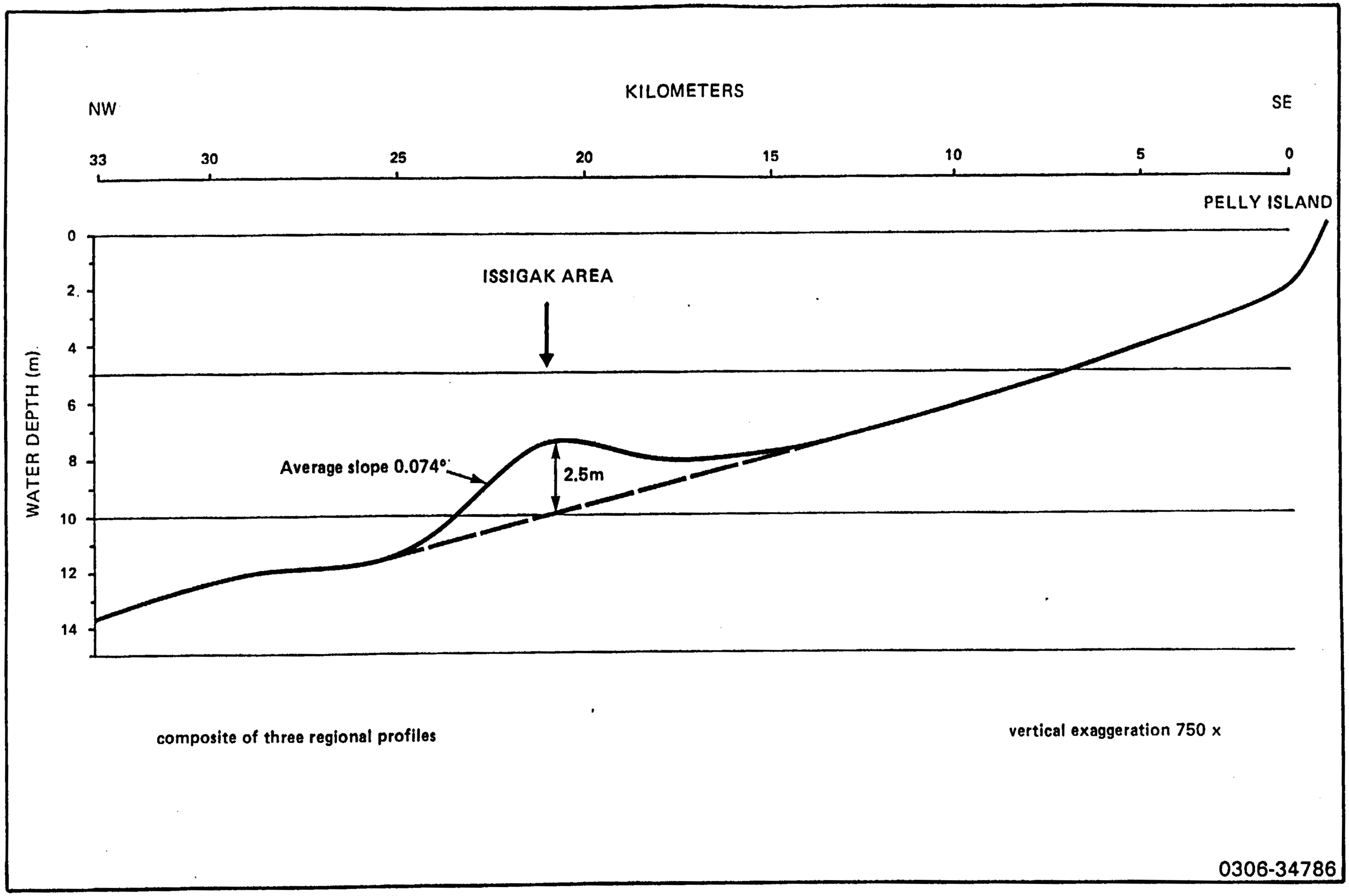


FIGURE 2 COMPOSITE REGIONAL BATHYMETRIC PROFILE FROM PELLY ISLAND THROUGH THE ISSIGAK AREA

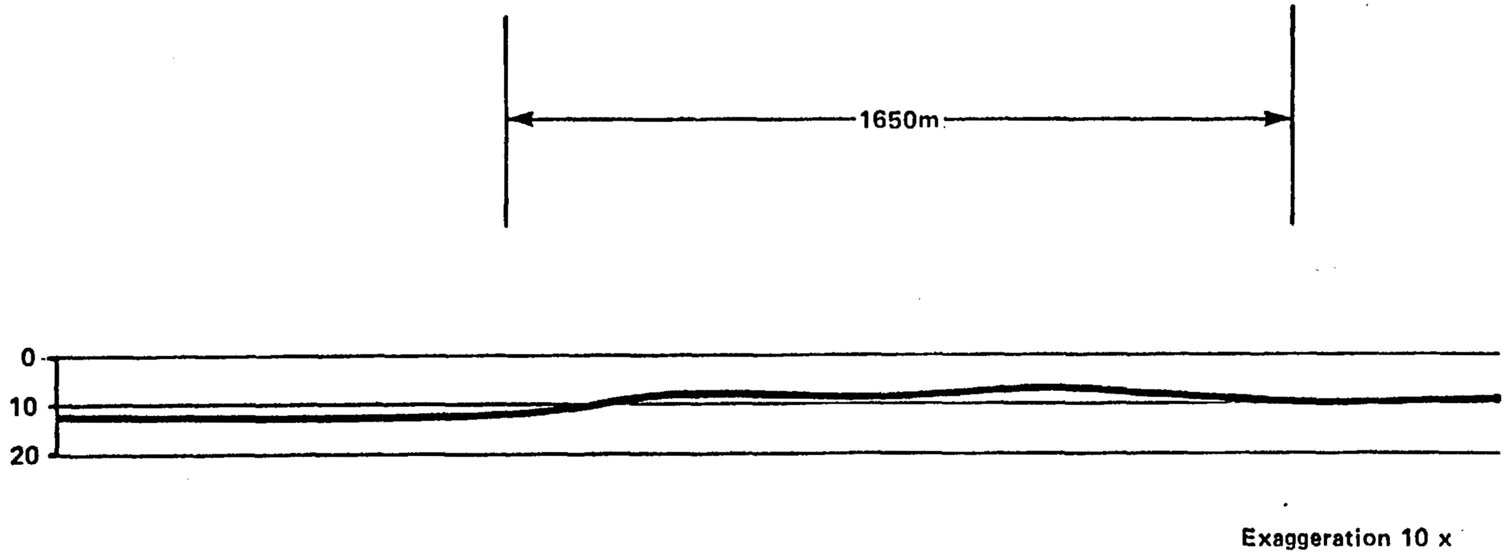


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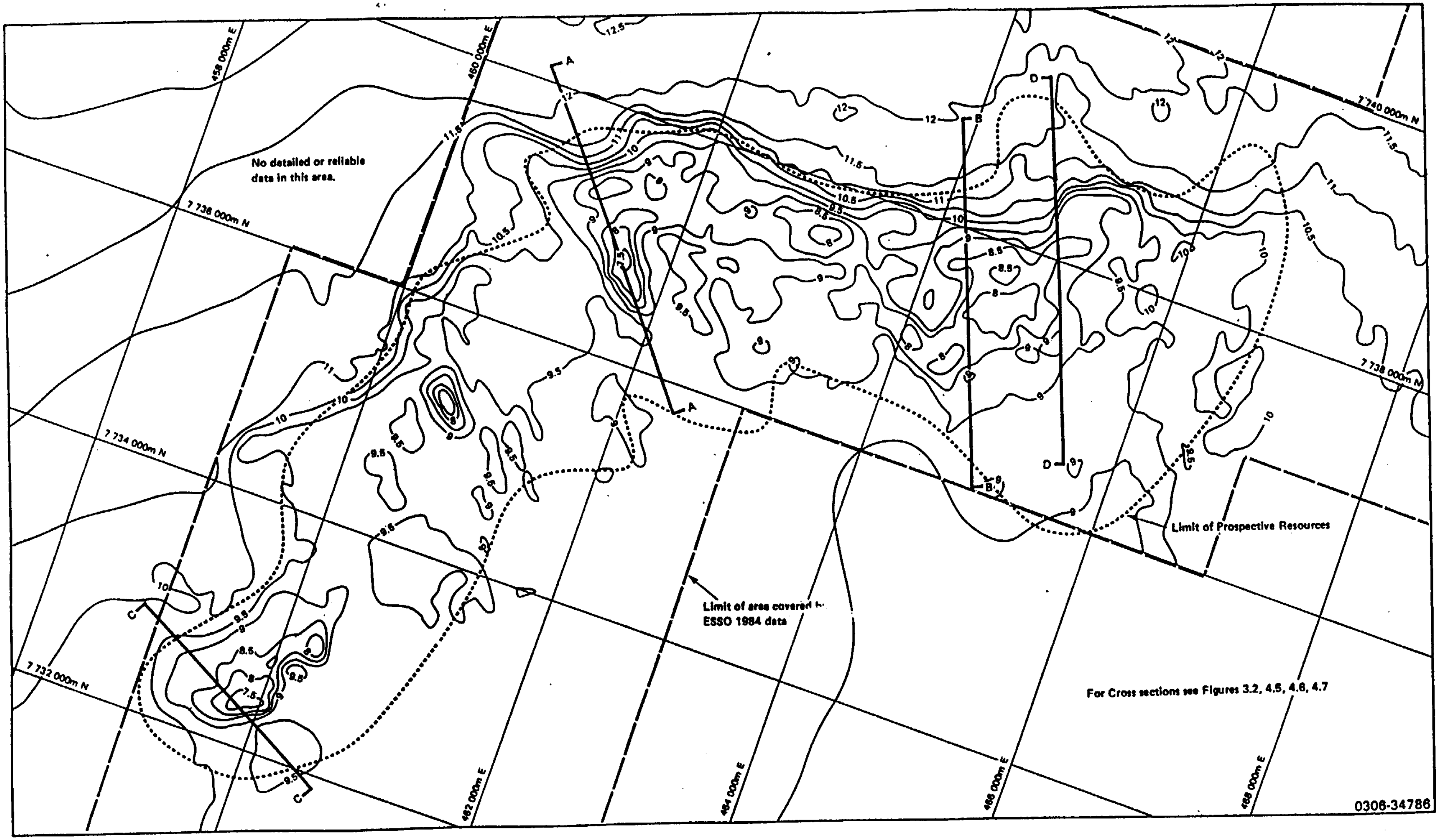
FIGURE 3 SECTION A–A THROUGH ISSIGAK DEPOSIT

EBA Engineering Consultants Ltd.



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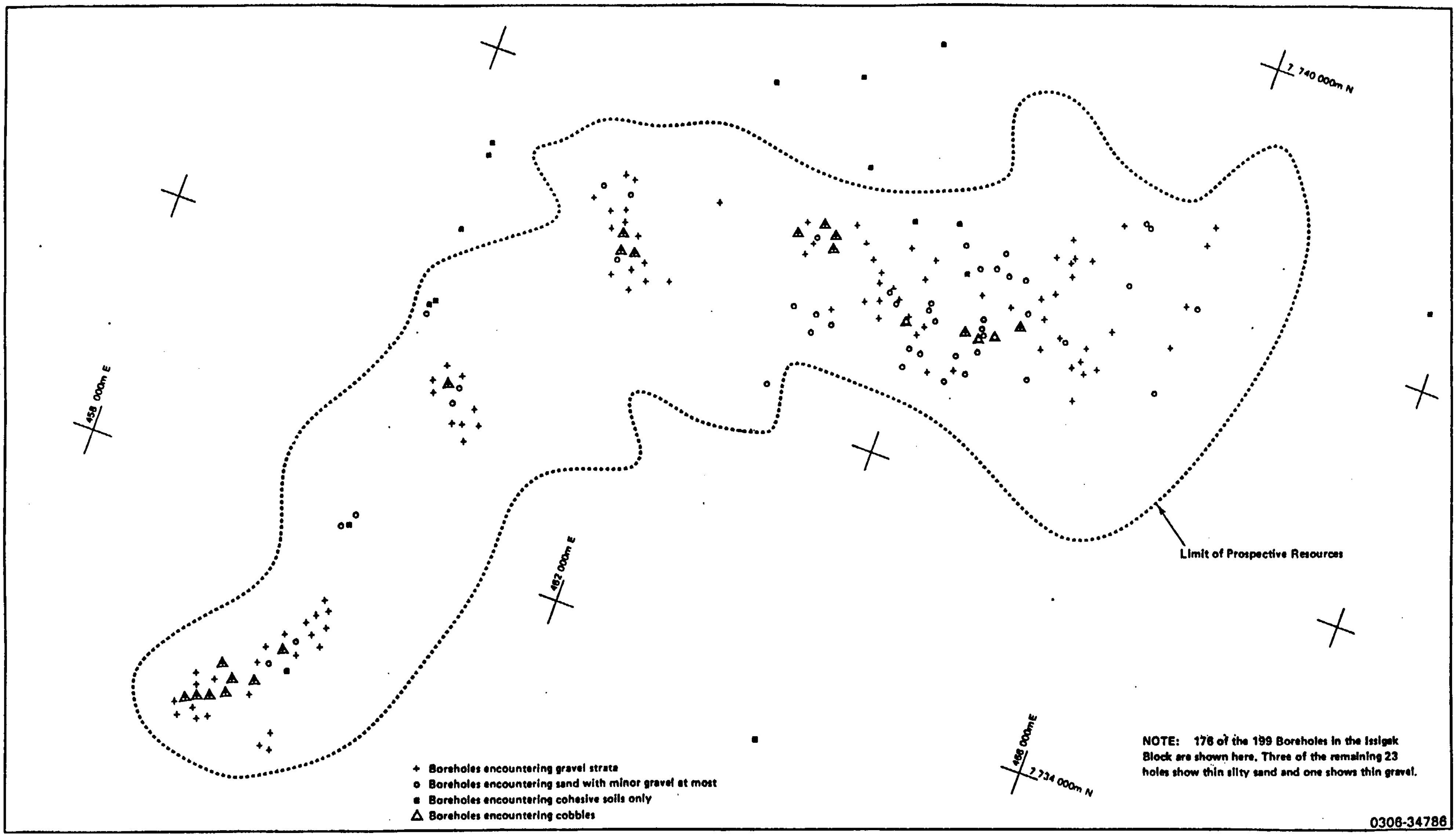
DETAILED BATHYMETRIC CONTOURS FOR THE ISSIGAK DEPOSIT

FIGURE 4



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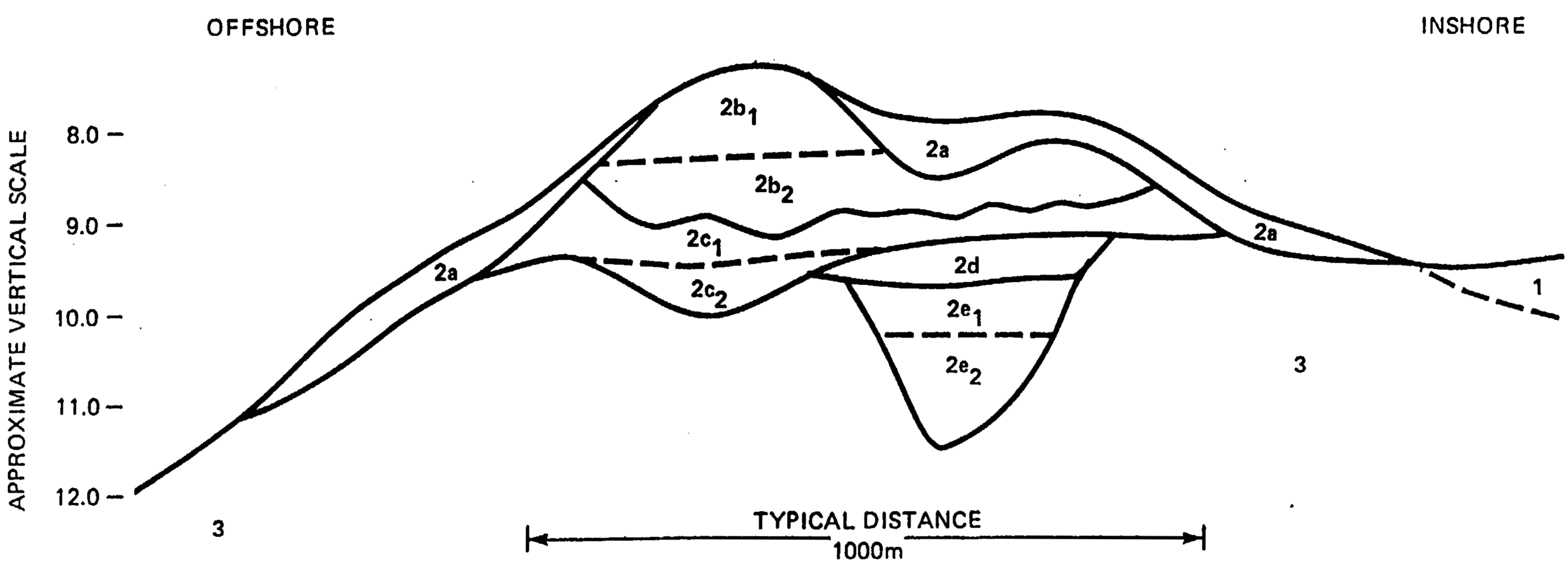
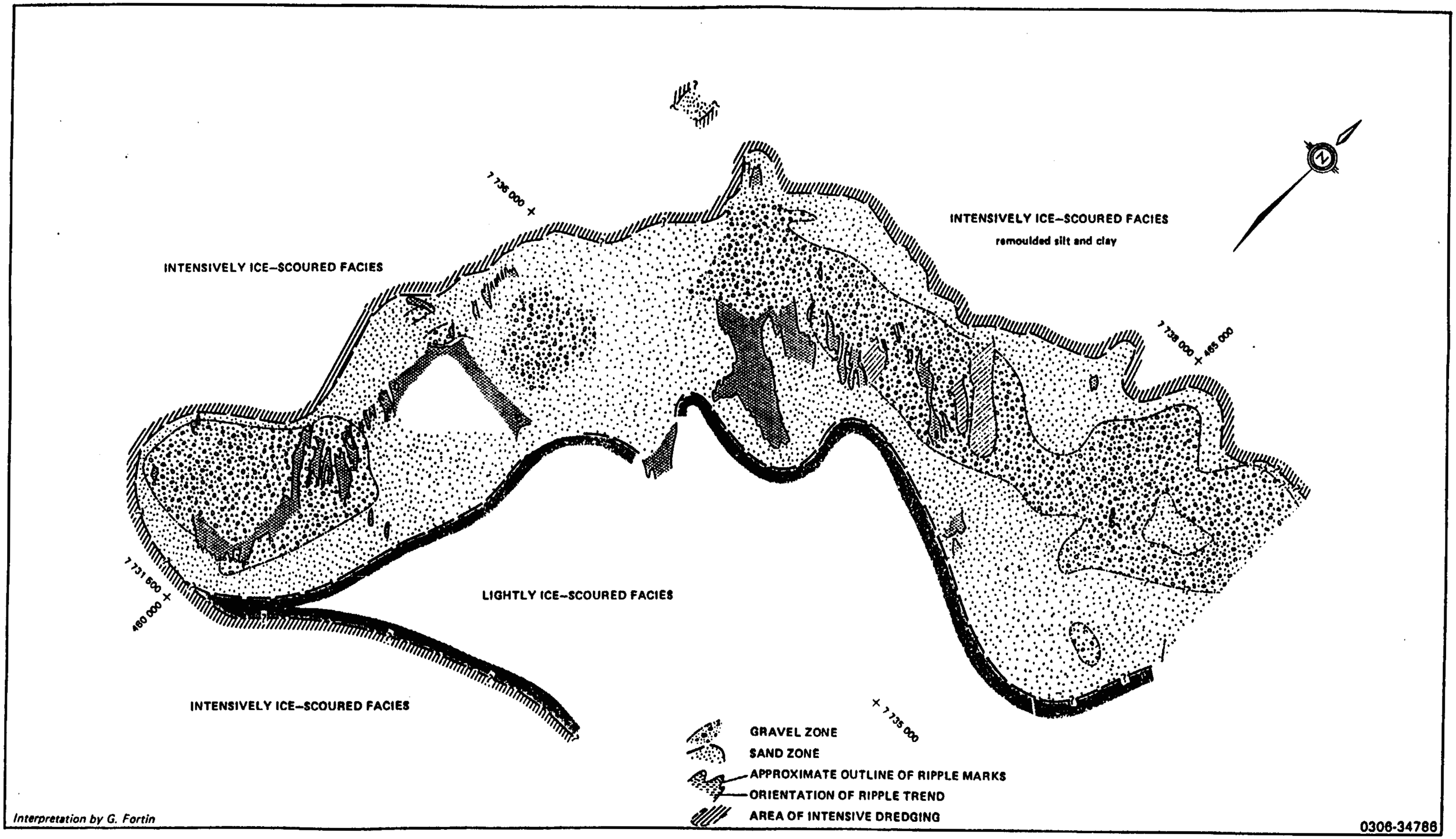
LOCATION OF BOREHOLES IN THE BORROW PIT AREA **FIGURE 5**



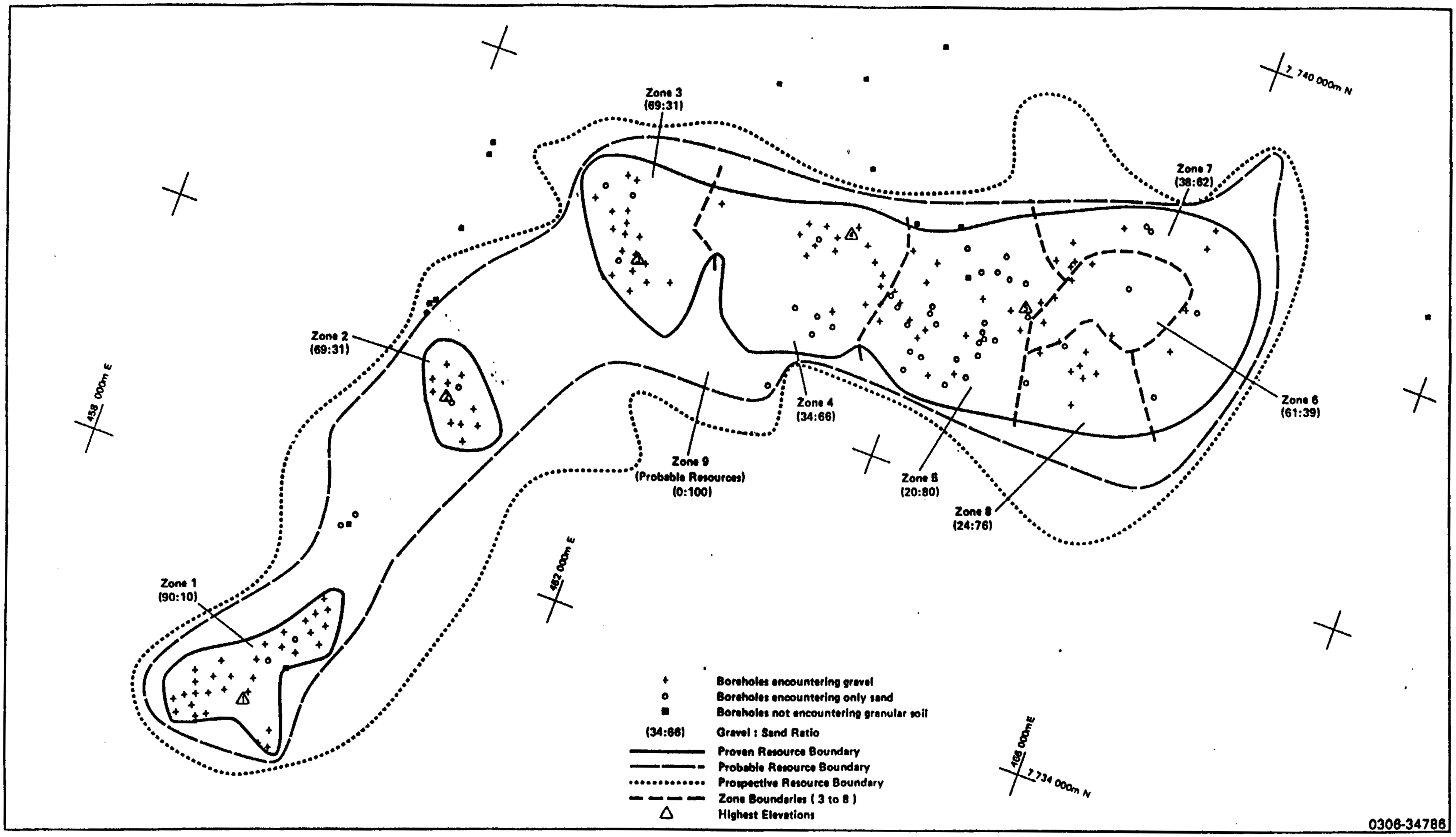
UNIT	DESCRIPTION	UNIT	DESCRIPTION
1	Silty Clay	$2c_2$	Silty Sand
2a	Clean Sand	2d	Silty Clay
$2b_1$	Sandy Gravel to Sand & Gravel	$2e_1$	Sandy Gravel
$2b_2$	Gravelly Sand	$2e_2$	Silty Sand
$2c_1$	Clean Sand	3	Silty Clay

0306-34786

FIGURE 6 **GENERALIZED STRATIGRAPHY OF THE ISSIGAK DEPOSIT**

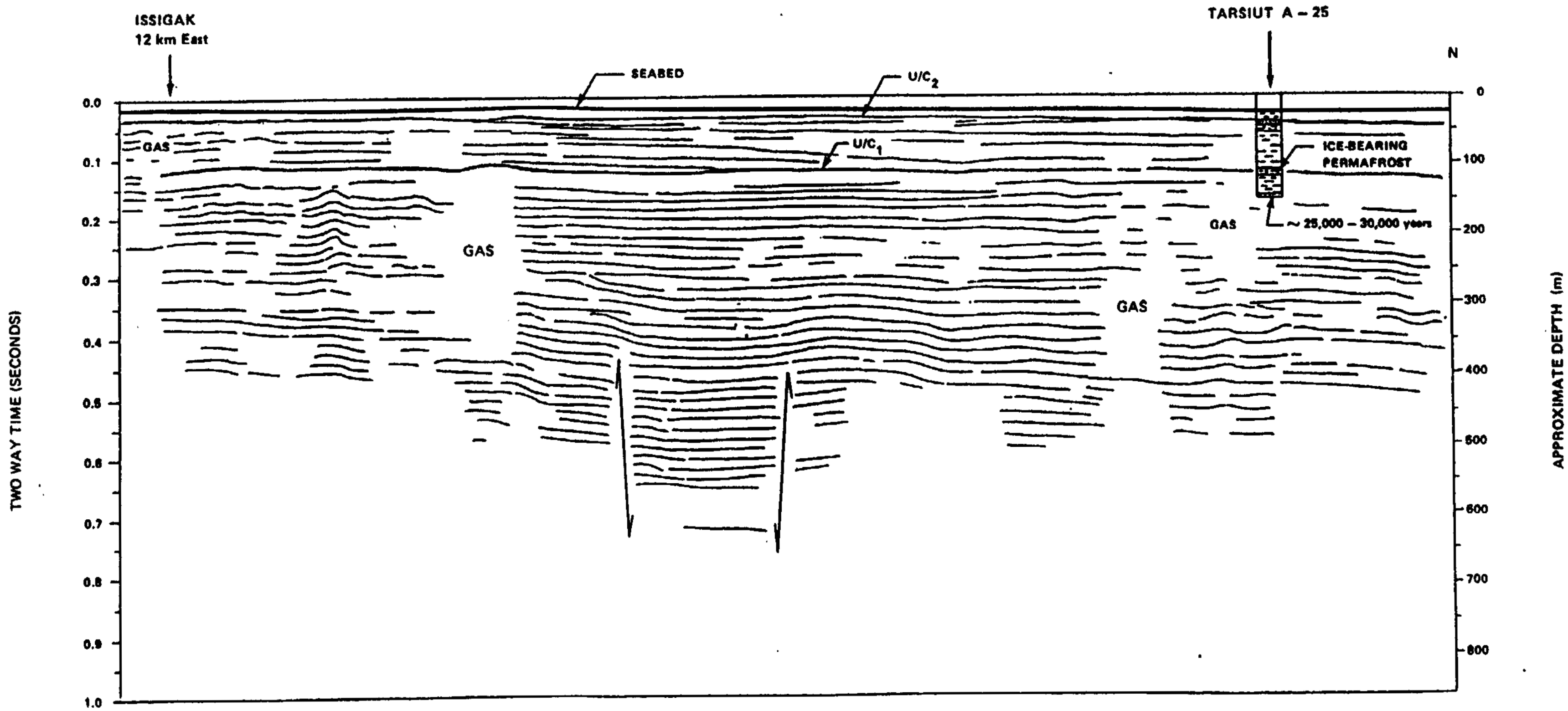


SIDESCAN INTERPRETATION OF SEABED CONDITIONS **FIGURE 7**



EBA Engineering Consultants Ltd.

RESOURCE & ZONE BOUNDARIES **FIGURE 8**



DATA SOURCE : MULTICHANNEL HI. RES. LINE DHR 80 – 530

Interpretation by G. Fortin.

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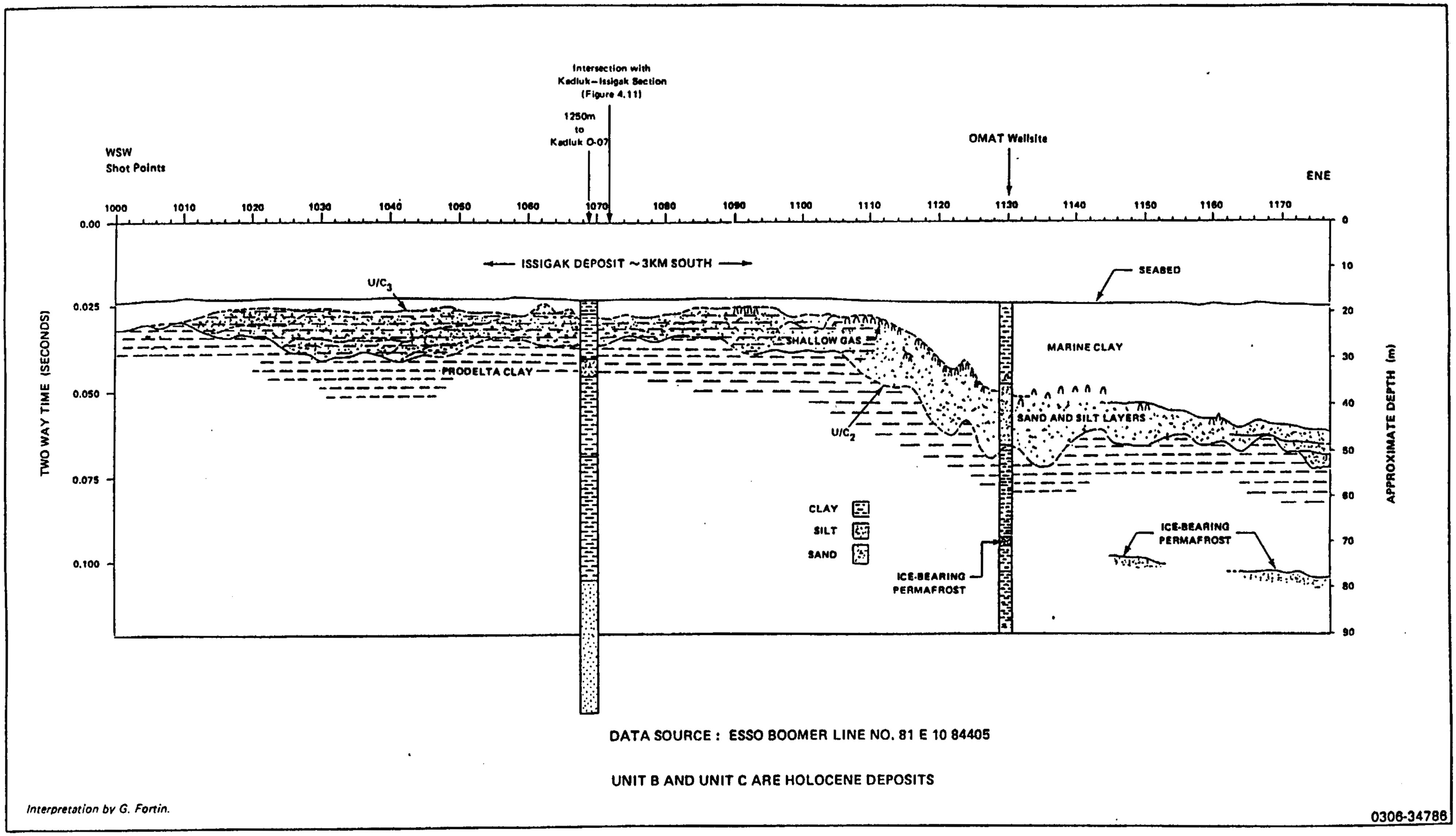
SHALLOW STRATIGRAPHY FROM TARSIUT A - 25 TO ISSIGAK AREA

FIGURE 9



EBA Engineering Consultants Ltd.

SURFICIAL GEOLOGY FROM OMAT WELLSITE TO AN AREA NEAR THE ISSIGAK DEPOSIT

FIGURE 10

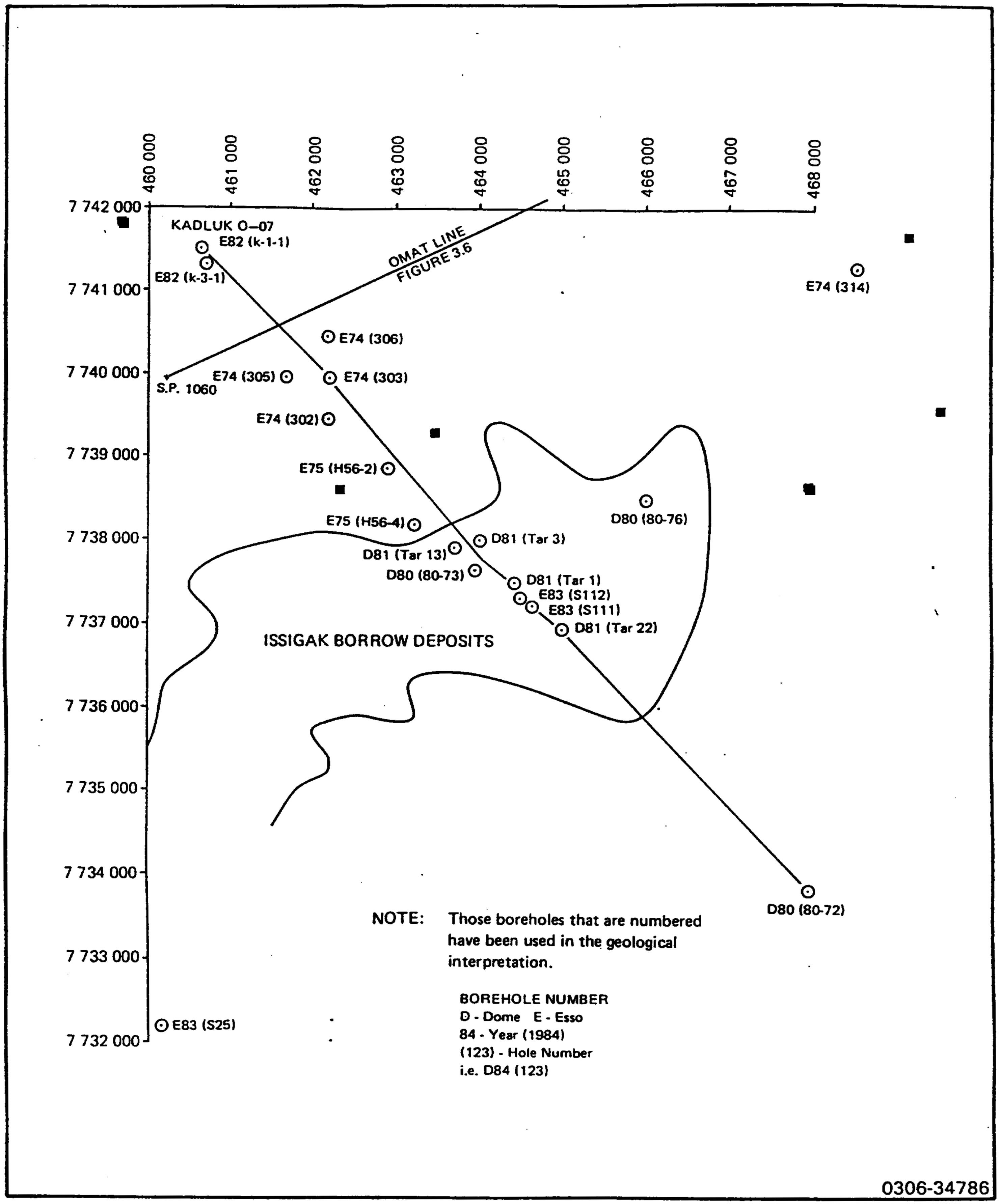


FIGURE 11 INTERPRETATION OF THE KADLUK–ISSIGAK REGIONAL STRATIGRAPHY

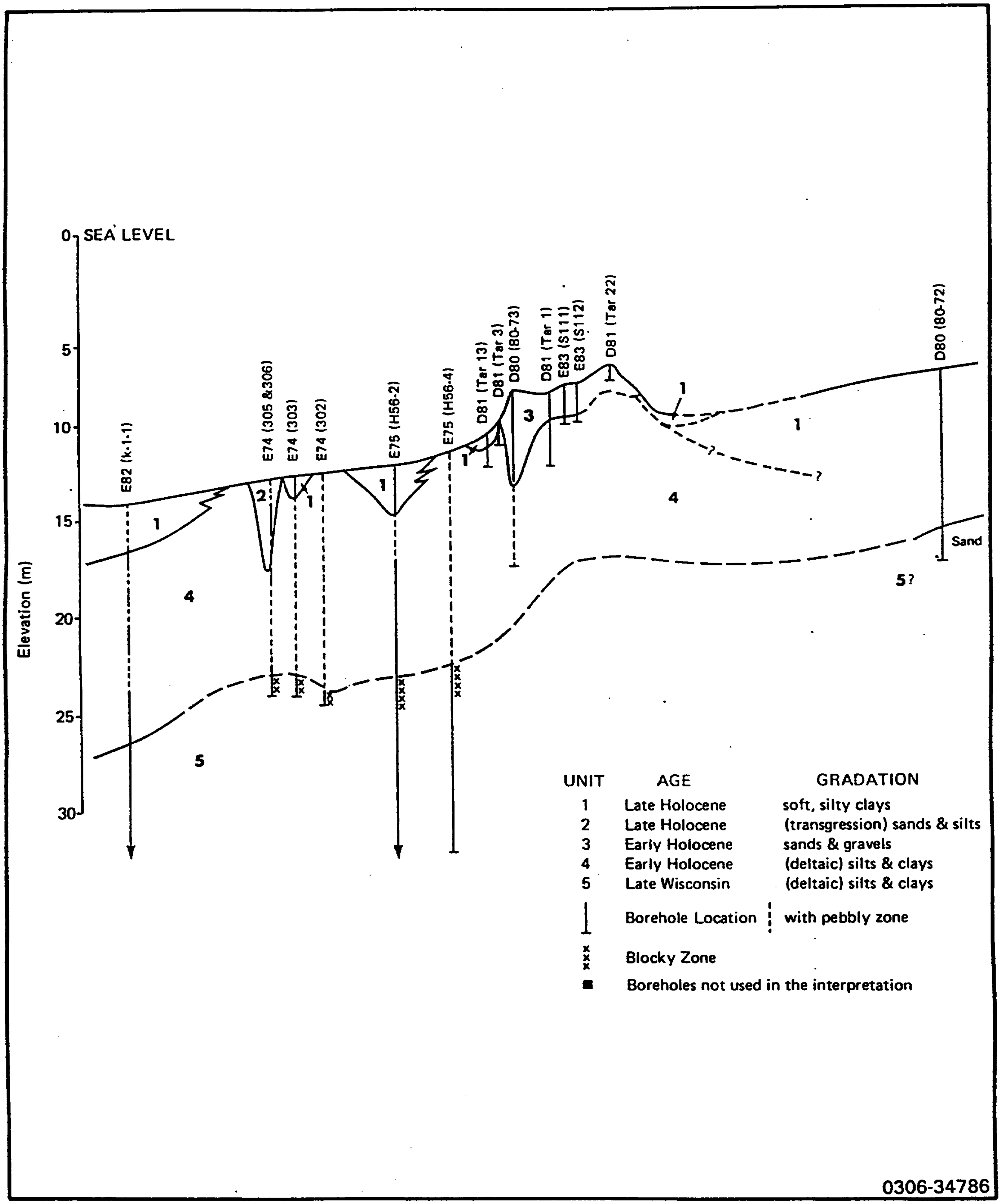


FIGURE 12 INTERPRETATION OF THE KADLUK–ISSIGAK REGIONAL STRATIGRAPHY

The Isserk Borrow Block
(NOGAP Project A4-20)

Presented By J.F. Lewis

Lewis Geophysical Consulting
Armdale, Nova Scotia

1.0 Introduction

The Isserk Borrow Site study program was one component of a set of concurrent studies that were initially conducted by Earth & Ocean Research Ltd. through 1987/1988. These studies consisted of a two volume borrow study conducted for DIAND of which Volume 1 is the Isserk site area and Volume 2 is the Erksak borrow site area which was discussed in Part A. The other study was a regional surficial geology program for the south central Beaufort Sea region which was completed for Steve Blasco of AGC. Steve will be discussing these regional geology results in a paper presented at this meeting.

Figure 1 is a map of the Beaufort sea showing the south central Beaufort geological study area and the two concurrent borrow block study areas. These borrow study reports were completed by EOR under DSS Contract AO632-7-5011/ C1ST for Mr. Bob Gowan of DIAND as a part of NOGAP Project A4-20.

This paper is specifically in reference to the western Isserk study region (Figure 1) which is a 20 km x 20 km area of 400 km^2 lying approximately 9 km north or Pullen island. The study region defined as to be within the following boundaries:

- Northwest: Zone 8; 520,000E; 7,770,000N (70°02'16"N; 134°28'30"W).
- Northeast: Zone 8; 535,000E; 7,770,000N (70°02'10"N; 134°04'53"N).
- Southwest: Zone 8; 520,000E; 7,750,000N (69°51'31"N; 134°28'47"W).
- Southeast: Zone 8; 535,000E; 7,750,000N (69°51'25"N; 134°05'22"W).

The specific purpose of this study has been to evaluate all (or as much as possible) of the geophysical and geotechnical data available within these regions with the primary mandate of attempting to quantize the locations and volumes of proven, probable and prospective granular resources that are present.

All three of the above referenced studies used a common data base set which was compiled and collated with the intent of using it over the three study programs mentioned above.

2.0 Data Bases

The mandate of these studies was to evaluate all high resolution geophysical and geotechnical data that had been collected in this study area. This consisted of a massive amount of data, though not all of this data could be found and accessed within a reasonable search effort for this study and a resulting more limited, though still significant, data set was actually used.

DIAND had initiated an earlier data compilation contract with McElhanney Services Ltd. which was a library search of the industry geophysical reports to identify the industry geophysical data sets that were initially collected (McElhanney Services Ltd., 1988). A second program with EOR was conducted to compile and digitize the geophysical track data (Peters, 1988) and a third with EBA to identify and compile the geotechnical data bases within the regions (EBA, Isserk 1988a, Erksak 1988b and Central Beaufort 1988c).

The initial tasks of this present study was to locate and copy as much as possible of the geophysical data sets for use within these evaluations. This was carried out over a month long period in Calgary with considerable appreciated help of the respective industry Beaufort operators. A number of the geophysical records couldn't be located and after a reasonable effort, it was decided to go with the data that had been collected.

2.1 Navigation/Geophysical Data Base

The track navigation and geophysical data compilations included the entire area of the south central Beaufort Sea geological study area.

Figure 2 shows the navigation track plots for only the industry operator survey lines that matched geophysical records that could be located and accessed for these study programs. Figure 3 shows the compiled navigation track plots of the government survey lines that were available to the study and were selectively accessed as required. Figure 4 shows the more limited area of the Isserk borrow site and the geophysical records available for just this area.

In general, the overall geophysical data set is of good, but variable quality. The quality is, however, dependent on weather conditions at the time of collection. Unfortunately, the

Isserk geophysical data set is an exception to this statement and is of limited use in determining stratigraphy equivalency of textural units between boreholes. There are a number of reasons for this.

- Significant data sets collected in 1983, 1984 and 1985 could not be located during the data search.

- Within the remaining data set, the line density is too low over much or the region to accommodate the high variability in texture and elevation of units within and between boreholes. The seismic data commonly shows many small local depressions or channel like features in the top of Unit C (basal sands) that are 100 to 500 m in width over relatively short distances along any line. To confidently map these details, a line spacing of 500 m or less is required which is not achieved in this data set. As a result, considerable interpretive licence has been required in the construction of contours of this surface and the detail of the borrow structures which will be discussed here.

- The data quality of the remaining lines is again variable and 30 to 40% of these lines are of relatively poor quality which further restricts their usefulness

These limitations largely restrict the litho-stratigraphic correlation of the Isserk Borrow Block to a study of the borehole stratigraphy and to the extent the seismic data can contribute, it has been incorporated into the geological model.

Appendices 1 and 2 of the text reports (Meagher and Lewis, 1988) describe the McElhanney data base which consisted of a compilation showing the surveys completed and line data originally collected and the results of the data search, respectively which describes the listed/found and copied data used for this study. Appendix 2 data base gives the locations of the original data as of April, 1988 and the copied data is currently resident at AGC in their data archives.

2.2 Geotechnical

The geotechnical data bases were compiled and inserted into ESEBase record form by EBA Engineering Consultants Ltd. for the entire south central Beaufort area. This data base project will be described more fully in a latter paper presented by Rita Olthof of EBA.

For illustration, Figures 2 and 3 show the locations of all of the almost 400 boreholes within the south central Beaufort area. Figure 4 showed the combined survey lines and the 99 borehole locations within the Isserk study area only.

The boreholes within the Isserk borrow block area tend to be clustered into four main groups within the region which were drilled for exploration island sites and a more regional area associated with previous work on the core area of the borrow prospect itself. Mr. Neil MacLeod of EBA, via a sub-contract to this study, assisted in developing a coding system for the sediments encountered within the boreholes which takes into account the sand and gravel quality and current dredging requirements and equipment restrictions of the Beaufort Sea operators. The coding system has been used in the figures describing the borrow prospects and has been used for evaluation of the borrow potential of the respective sites when boreholes are available. This coding system is reproduced on the maps of the detailed borrow prospects discussed later. For detailed discussions refer, to Meagher and Lewis (1988a and b).

3.0 Site Descriptions

3.1 Physiography

The Isserk Borrow Block area lies on the Akpak Plateau (O'Connor, 1982) in 8 to 24 m of water (Figure 1). This region is a submerged upland physiographic region located in the south central Beaufort Sea. The Akpak Plateau is a trapezoidal shaped region of slightly convex seaward bathymetric contours trending almost northerly from the area of North Point on Richards Island virtually out to the shelf edge. It is bounded to the east by the Kugmallit Channel and to the west by the Ikit Trough. The area is characterized by an elevated regional unconformity surface defining the top of Unit C relative to the adjoining depression areas.

3.2 Bathymetry

Figure 5 is a contour map of the bathymetric contours over the Isserk site at a 1 m contour interval. These contours are considerably smoothed as the contours were developed by a re-contouring of the CHS worksheet which were surveyed in 1969 and 1971. These worksheets were displayed at a 1:100,000 scale and line spacings were 800 to 1,500 m. The region has been resurveyed in 1985/1986, though the newer data was not available at the time of this study and it is anticipated that the this newer data, which is more accurately positioned and of a higher line density, will modify the shape and detail of the contours to some degree.

Overall, the contours show a gently dipping plain dipping northward over the southern half and to the north-northeast over the northern half of the site. The seafloor is slightly raised along a north-south axis through the west-centre of the site and again along a northwest-southeast axis near the southeast corner. The ridges are separated from each other and are possible expressions of different geologic features.

Water depths over the site vary from a minimum of 8 m in the southeast corner to a maximum of 24 m in the northeast corner.

4.0 Surficial Cover

The surficial cover over the Unit C sand material is displayed in Figure 6. The construction of this surficial cover map has been defined directly from borehole information and by inference from the seismic data. The map indicates two surficial clay units and a coarser zone of potential borrow materials.

The coarse material occupies roughly the central and west-central part of the block and extends toward the southeast to the southern border of the site. Sample data from the boreholes is available for the coarse material located in the central portion of the deposit. The coarse material is predominantly composed of poorly graded fine sands to silty sands. The sands are non-cohesive, olive brown to dark brown. Occasional gravel clasts from 15 to 25 mm in diameter occur throughout the deposit. The gravel clasts, where described, are polished and sub-rounded. The gravel content increases in pockets located along the southwest edge of the coarse deposit where it is equally dominant with the sand. These deposits are noted as being "gap graded" with the gravels being fine textured and the sands being poorly sorted fine to medium textured.

There are no boreholes within the portion of the coarse zone that extends from the central deposit to the southeast and beyond the southern boundary to the south. Seismic evidence suggests that this zone is composed of a combination of two geologic units. The younger unit is an extension of the central deposit and it is inferred that the texture of this extension will be similar to that of the central zone, i.e., generally poorly sorted silty sands with some gravel. The unit is defined by the transition of the surface character on the micro-profiler and boomer records from an irregular micro-relief to a featureless micro-relief. A slight doming of the seafloor is associated with this change in seismic signature.

The older unit extends from the south and is in contact with the younger in the south-central area. No borehole textural information is available for the deposit within the site, although recent testing of the unit immediately to the south of the block reveals coarse sand and gravel at the seafloor (S. Blasco, personal communication). The boundary of the deposit as outlined on the map, is defined as that area where Unit C rises to within two metres of the seafloor. The seismic data available are not of a sufficient resolution to measure the depth of the unit within this zone and there may be areas within this boundary that are very close to the seafloor. The micro-profiler data do not show the smooth seafloor trace characteristic of sand size sediments at the seafloor across this zone and the deposit may be covered by a thin soft veneer.

The fine material surrounding the coarse deposit consists uniformly of inorganic clays with very occasional black organic streaks. They are generally low to medium plastic with a water content that varies from about 20% to 45%. The clays also vary from soft to very stiff. Trace amounts of sand in fine laminations are noted in several samples as well as trace amounts of silt and shells.

While clay samples from throughout the area share this general variability, those of the Issungnak O-61 group of boreholes (IS78-series) at the northern boundary of the block are more consistently of high plasticity. Those of the Itoyuk I-27 (IT81-series) to the east, Isserk B-15 (B-15-series) to the south and Issungnak South (S81-series) to the west are virtually all low plastic clays. This suggests that the Issungnak O-61 surficial clays are a different body than the clays to the south, a suggestion that is tentatively supported by the seismic data. A somewhat arbitrary boundary has been drawn across the northern end of the survey site to note this change in stratigraphic units.

5.0 Subsurface Geology

The sub-surface geology within the site can be described within the framework of O'Connor's stratigraphic model for the Beaufort shelf. Units A, B and C are identified and facies within these units discerned. The near surface litho-stratigraphy and structure are complex and distinct changes in seismic character are observed vertically and horizontally along individual seismic profiles. Continuity in the seismic data is generally poor and the ability to confidently follow seismic horizons from line to line is low. While varying in detail, the boreholes present a more consistent picture of the general stratigraphy.

Three borehole transects have been constructed; a north-south transect, an east-west transect and a southwest-northeast transect. These are presented as Figures 7, 8 and 9. The orientations are approximate and the transects do not form straight lines as they are determined by the distribution of the boreholes. The geographic positions correlating to these transects has been shown on the seismic track plot and borehole map of Figure 4.

6.0 Top of Unit C

The lowest regionally persistent horizon is a composite of a younger and an older erosion surface, the equivalents of U/C1 and U/CL. The character of each in the borrow block area is distinctive and they are distinguishable one from the other where data quality permits.

The older unconformity forms a highly incised, irregular surface. The surface has been removed by the subsequent erosion episode (U/C1) over the crest of the site and to the east as the Kugmallit Channel is approached. The seismic profiles indicate the irregular lower surface to descend to the east and west from a central high. The extreme irregularity of the horizon suggests an old sub-aerial erosion surface that has not been affected by the transgression.

The structure map presented in Figure 10 describes the shape of the upper surface of Unit C (U/CL unconformity). Where the younger erosion surface has excavated to the top of Unit C, it forms a smooth, featureless plain. The remnant areas that were not affected by this erosion episode display a highly dissected pattern. The surface descends to the north, east and west from an irregular crest that extends from the southeast edge of the site through approximately the site centre and beyond the site boundary to the northwest. The surface descends from a high of 10 m near the southern border, where it lies at or near the seafloor, to 34 m at the northwest edge of the survey coverage. As the surface descends, there is progressively less planation by the later erosion episode, with the result that the map displays an increasingly more complex topography to the north.

7.0 Depositional Summary

Predominantly fine to medium sand was deposited as Unit C through channel cut and fill processes in a locally variable, but generally moderate to high energy fluvial or glacio-fluvial environment. Potentially coarser and more resistant material was deposited as a linear body that extended from the southeast corner of the site through the site centre. Subsequent to this deposition, the surface of the unit was down-cut under sub-aerial conditions to form a highly irregular topography of small channels and mounds (Figure 11a). The more resistant body was down-cut to a lesser extent and formed the positive core for the plateau in this area. During this period, material was moved downslope via the gullies and also on the interfluves via dune formation. On the eastern flank of the plateau, leading down into the Kugmallit Channel, coarse material was aggraded into dune-like bed forms that indicate sediment movement to the east into the channel.

The sculpting of the highly incised topography was followed by a marine transgression that initiated the deposition of Unit B (Figure 11b). Preservation of much of the sub-aerially constructed topography on Unit C suggests that the initial transgression across this area was rapid. Predominantly fine material was deposited in the depressions on Unit C. As the sea level rose, planation of the raised part of Unit C occurred and produced local lag gravel deposits that remained in contact with the source material. A distal sand facies spread out over the clays deposited on Unit C in the basinal areas. This was followed by a period of shallow marine deposition of fine material. A short second regression was followed by a slower transgressive rise in relative sea level, during which time the raised portions of Unit C and the previously deposited Unit B strata were reduced by wave base planation to a smooth surface (Figures 11c and d). The elevated section of Unit C to the south and the previously re-worked Unit B sands and gravels provided the source material for a thin coarse grained deposit centred over the crest of the site. Fine grained clays were deposited coevally away from the crest of Unit C.

With continued transgression, the wave base moved away to the south and the construction of the sand body ceased. The upper sand body was buried by marine clays in the deeper water area to the north. With continued shoreline retreat, this process may be on-going. At present, however, most of the Isserk Block area is floored by old sediments laid down during the most recent transgression.

8.0 Granular Resource Model and Evaluations

The granular resources of the Isserk Borrow Block are located in two geologic deposits of different age, distribution and depositional mode. The upper deposit represents a re-worked deposit associated with Unit B, while the lower deposit consists the Unit C basal material. The distribution of the surficial prospect material is displayed as Figure 12 and the distribution of the lower prospect is shown in Figure 13. These maps incorporate divisions of the reserve into proven, probable and prospective zones. Proven granular resources are defined as those resources whose occurrences, distributions, thickness and quality are supported by considerable ground truthing information such as dredging and/or geotechnical drilling data. Probable reserves are defined as sands and gravels whose existence, extent and quality has been inferred on the basis of limited ground truthing information and/or several types of indirect evidence including side scan sonar, shallow high resolution seismic, echo sounding and/or bathymetric and/or geological considerations. These estimates are based on an understanding of the proven reserves as determined from boreholes and a comparison with the seismically mapped prospective regions to provide an estimate of probable resource that may represent a viable planning figure for future utilization. Prospective resources are defined as granular resource deposits whose existence and extent are speculated on the basis of limited indirect evidence, such as ripple marks on side scan sonar records or general geological considerations.

Within the Isserk Borrow Block area measurements of overburden and resource thicknesses were made for each borehole. These analyses have revealed that there are two distinct bodies of sand flooring the Isserk block, with the lower sand being ubiquitous and the upper sand being of local extent.

Because of the applicability of this two resource model, the boreholes have been coded and are described in terms of a first encountered coarse unit and a second encountered coarse unit. This allowed spatial display of these data on the map sheets and subsequent contouring and definition of the two prospect areas. From observation, it is apparent that where there is only one sand unit present and the borehole longer than about 10 m, the sand unit present is the older of the two. The only instance where this may not apply is Borehole IB80-84 near the centre of the Isserk block where the upper and lower sands may be in contact with each other.

8.1 Upper Surficial Prospect

The main body of the deposit is roughly triangular in shape and located in the west-central part of the block (Figure 12). A narrow, linear "tail" extends from the southeast edge of the main deposit to near the southeast corner of the block area.

The spatial distribution of this deposit is defined on the basis of borehole control and the seafloor character of the boomer and profiler records. Coarse material on the seafloor, as identified in the boreholes, is associated with a distinct change in character on the seismic records.

While the map in Figure 12 displays the areal distribution of the deposit for the proven, probable and prospective zones, contours indicating the thickness of the deposit are only provided for the proven zone. The thicknesses are derived solely from the borehole logs as the base of the deposit was not observed on the geophysical data.

Twenty-five boreholes have been drilled within the boundaries of this zone. Borehole penetration varies from 4.5 m to 21.4 m with 17 boreholes less than 10 m long. The majority of the boreholes encounter sand at the seafloor and silty or clayey deposits at from 1.25 to 3 m below seafloor. Two boreholes, IB80-84 and IB80-96, record sand from the seafloor to their depth of penetration. Borehole IB80-84 was drilled to a depth of 21.4 m and borehole IB80-96 to a depth of 9.1 m. Three boreholes record a veneer of clay atop the surficial sands. The veneer varies from 0.2 m to 0.6 m. The boreholes IB80-95, IB80-93 and IB78-5 are located in proximity to each other and the clay deposit may form a continuous veneer along the western side and northern tip of the zone.

The proven resource is primarily based on the borehole information and occupies the central part of the deposit with the displayed boundaries defined by both borehole and seismic data. Within this zone, there is a very high confidence that useable granular material occurs. Based on the borehole data, this zone has been further subdivided into zones dredgeable by hopper dredge only and by both hopper and stationary dredge methods. These subdivisions are shown by the heavy dash-dotted line subdivisions within the proven area. The position of these lines has been made using the dredgeability assessments and the development concerns assessment of each of the boreholes and using a simple rule of equidistance between the boreholes within the proven reserve area. Based on these subdivisions, two small regions associated with boreholes IB80-96 and IB80-84 are defined which are categorized as dredgeable with either hopper or stationary dredge. It is assumed that below the approximate 4 m level in each of these regions, one would be mining the lower sand resource as opposed to the upper re-worked Unit B materials.

The probable resource boundaries are based on seismic and limited borehole information. This area is seen to rim the proven region with a tail defined which extends approximately 8 km off toward the southeast from the main body of the deposit. This tail region is defined exclusively with the seismic data.

The prospective region is defined entirely on the seismic data set and is based on bottom character return along with faintly defined internal reflections seen within the data. It may represent an extension of re-worked Unit B materials; however, borehole information would be required to confirm this.

8.2 Lower Basal Prospect

The Lower Basal Prospect represents a region where the unconformity surface representing the top of Unit C comes to within 3 m of the seabed. The 3 m limit has been taken as the practical limit of overburden stripping when a Stationary Suction dredge is utilized. This region is located in the southeastern corner of the prospect area and is highly irregular in shape (Figure 13).

This region is defined almost entirely from mapping of the seismic data and is only confirmed by boreholes in the extreme northwestern tip of the area. Because of this lack of borehole confirmation, the entire prospect is considered to be prospective only at this time. Although some limited quality information is available, the boreholes indicate this lower unit to be highly variable in nature and considerable confirmation drilling will be necessary to confirm this region as a viable resource.

9.0 Resource Prospect Granular Volume Estimates

Table 1 summarizes the estimates of proven, probable and prospective volume of granular resource for the two prospect areas defined in this report. The methods of volume calculation vary slightly for the two prospects in that the upper sand is assumed to represent a body which is exposed at the seafloor and no stripping is required, thus mining is limited to the thickness of the resource. In this case a minimum thickness of one metre is required and volumes are calculated based on the area between the contours times the average thickness assuming a linear proportion distribution between the contour lines (ie. area = 10 m^2, between the 2 and 3 m contours; therefore, volume = 10 m^2 x 2.5 m = 25 m^3). For this upper material, the total volume is taken as the sum of the volumes between all thickness contour lines. The total probable and total prospective resources incorporate the volumes of the higher probability materials.

Within the lower sand body, volumes are calculated based on an assumed thickness of the resource material which reflects the assumed maximum depth of dredging capabilities. Since detailed evaluations of the depth of the resource are not possible at this time, these values are taken as estimations only.

10.0 Conclusions

The Isserk Borrow Block of the south central Beaufort Sea covers an area of 400 km^2 and contains significant amounts of proven, probable and prospective granular resource materials. Through the integration of geophysical, geotechnical and geological data collected over the past 15 years from both industry and government operators, two main deposits were identified. These deposits occur as fine to medium grained sand bodies that lie within a complex sequence of glacio-fluvial, fluvial and transgressive marine type sediments that form a northwest-southeast trending ridge across the Akpak Plateau.

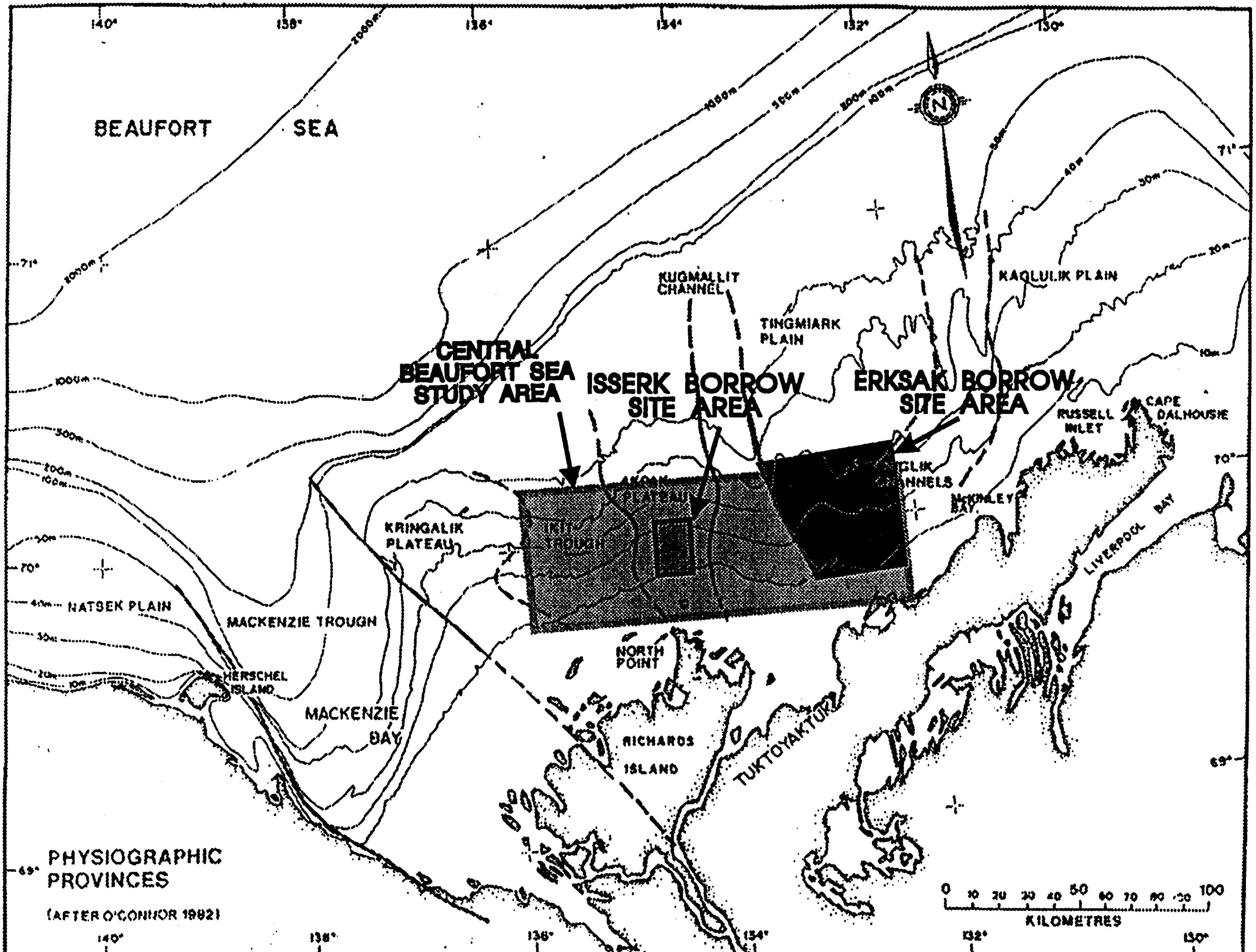
The first deposit (Upper Sand Unit) is a localized shallow sand body which lies in the central portion of the Isserk Borrow Block. Its triangular shape covers an area of approximately 53 million square metres. Borehole and seismic data indicate an estimated 19 million cubic metres of proven, 63 million cubic metres of probable and up to 80 million cubic metres of prospective granular resource materials. The proven resource estimate is based primarily on borehole information and subdivided according to dredging and development concerns.

Table 1
Granular Resource Volume Estimates
Isserk Borrow Block

Unit Thickness (m)	Area ($m^2 * 10^6$)	Volume ($m^3 * 10^6$)
Upper Sand Unit Exposed at the Sea Floor:		
PROVEN RESOURCE		
>1<2	4.483	6.73
>2<3	4.964	12.41
>3<4	5.534	19.37
>4<5	2.896	13.03
>5<6	1.185	6.52
Total Proven Resources	19.062	45.03
PROBABLE RESOURCE		
Assume 1 m minimum	18.006	18.01
Total Resource	37.068	63.04
PROSPECTIVE RESOURCE		
Assume 1 m minimum	16.711	16.71
Total Resource	53.779	79.75
Lower Sand Unit:		
PROSPECTIVE ONLY Portion of Unit C covered by 3 m of overburden or less.		
Assume 1 m	40.840	40.84
Assume 5 m	40.840	204.20
Assume 10 m	40.840	408.00
Assume 20 m	40.840	816.00

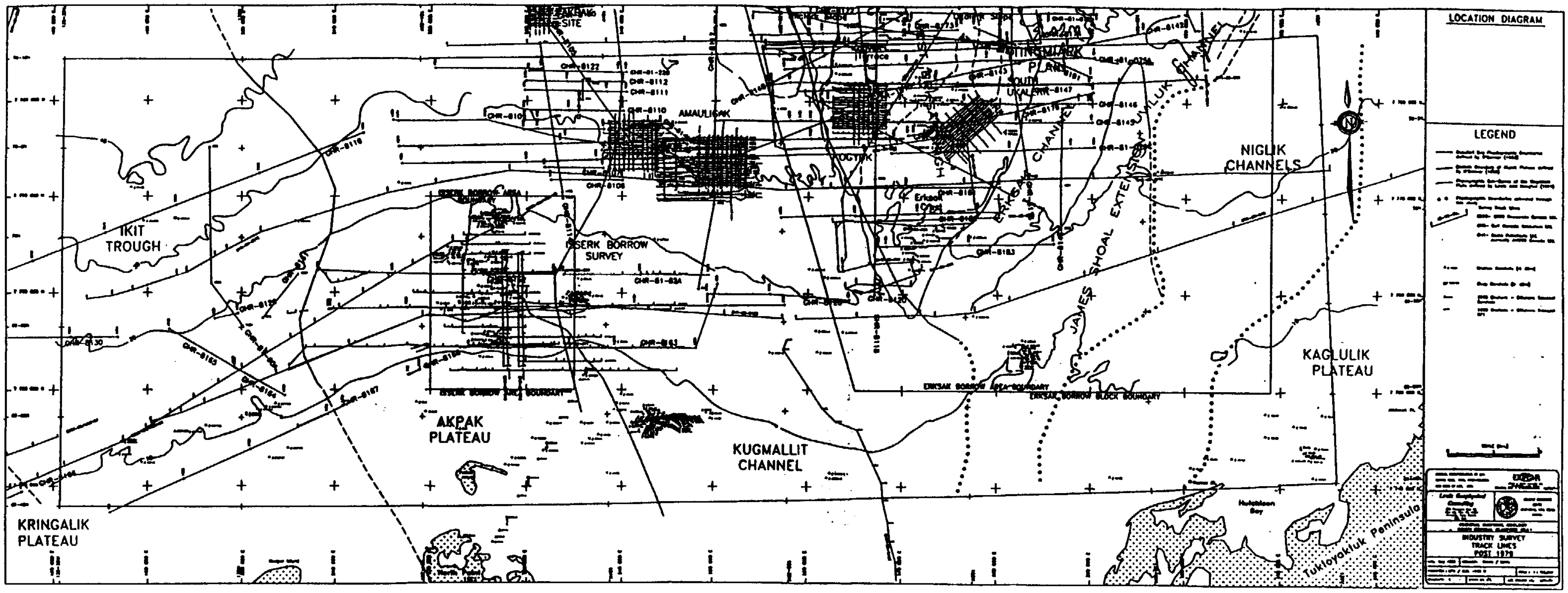
The second deposit (Lower Sand Unit) is a near surface exposure of Unit C which lies in the southeast quadrant of the study area. It is estimated 800 million cubic metres of prospective granular resources is based on limited seismic information only and requires considerable future ground truthing. Of this 800 million, it is likely that only 100 to 300 million might actually be recoverable when permafrost bonding and resource quality are fully considered and delineated.

It is conceivable that the Lower Sand Unit extends beneath the Upper Sand Unit to the northwest, separated, however, by a clay layer of variable thickness. The actual extent and quality of this deposit can only be determined through further investigation.



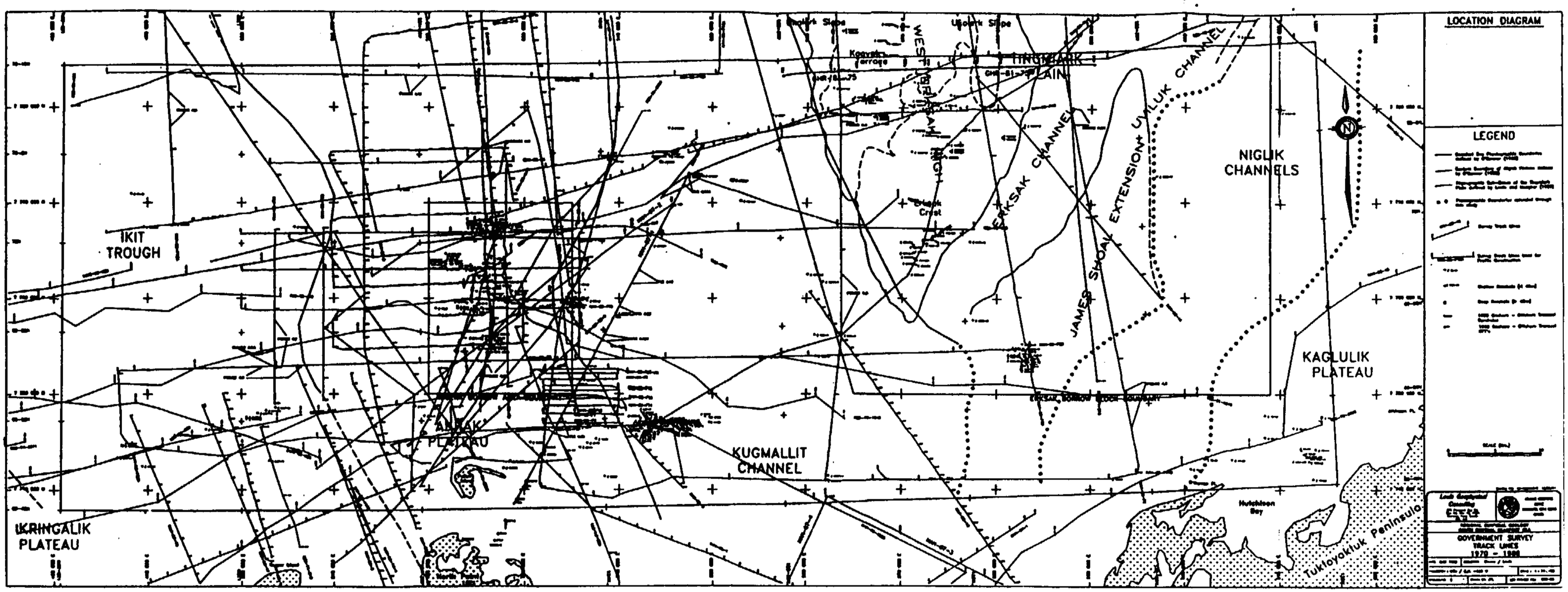
LOCATION DIAGRAM

FIGURE 1



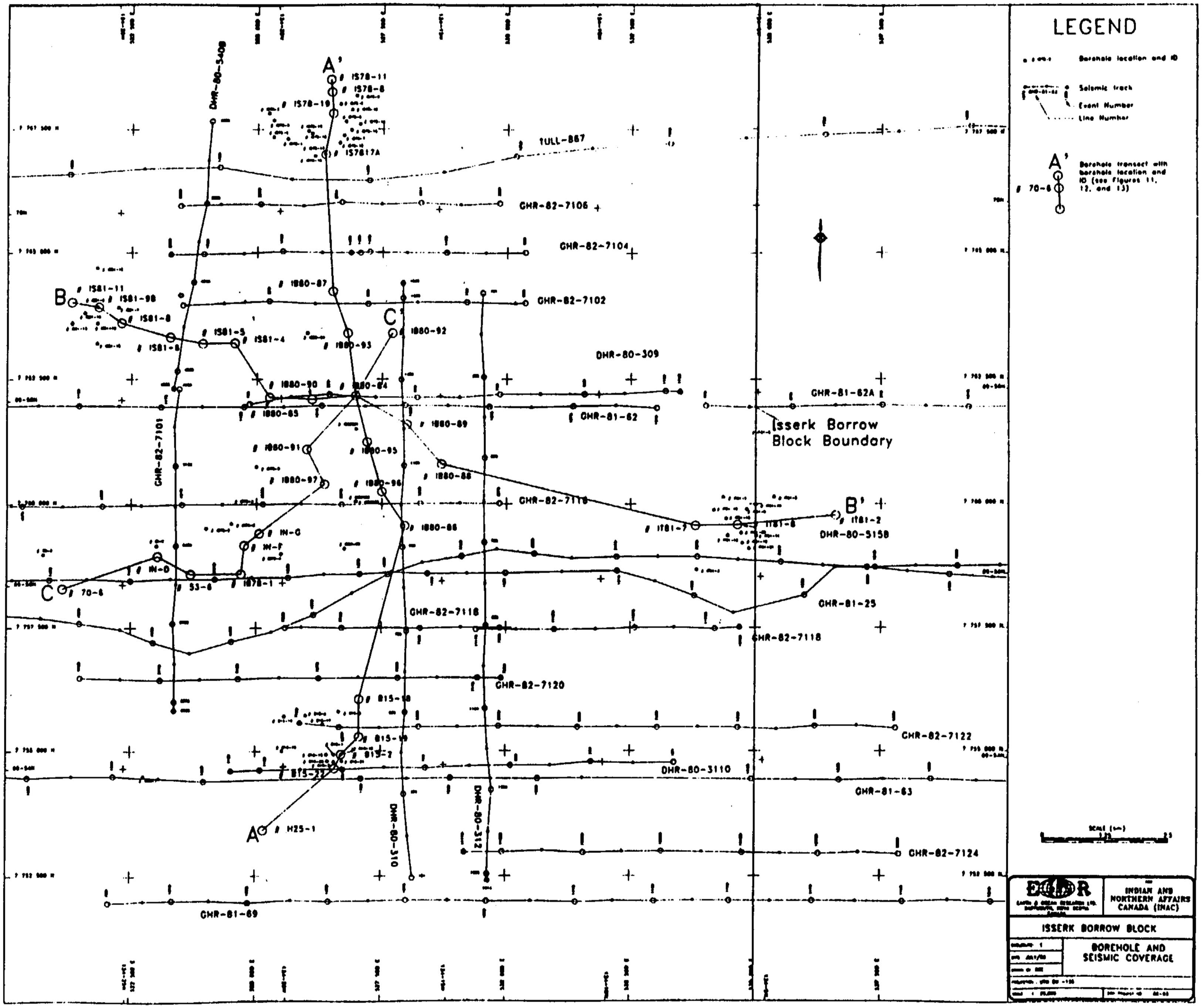
INDUSTRY SURVEY TRACK LINES POST 1979

FIGURE 2



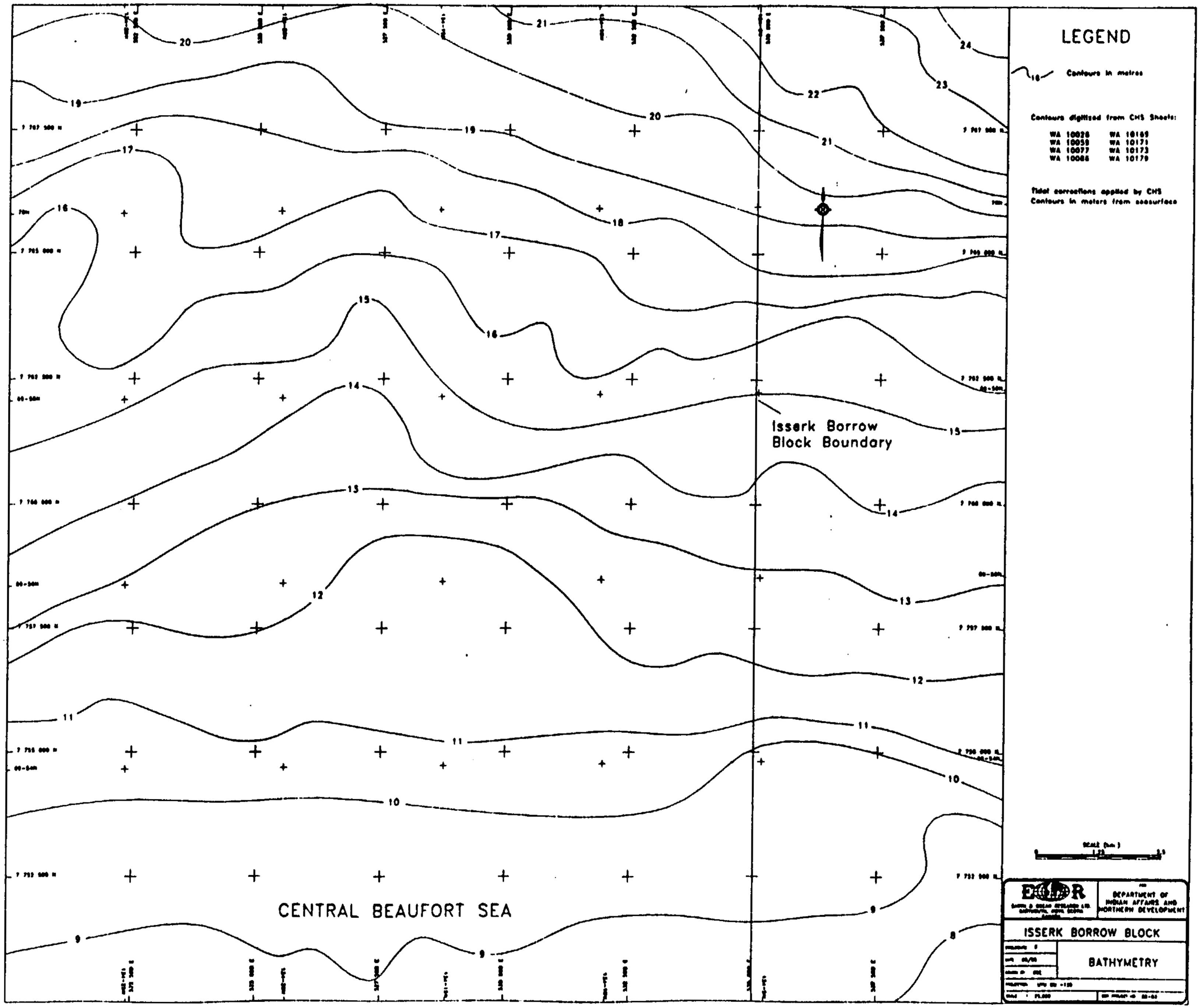
GOVERMENT SURVEY TRACK LINES 1970 - 1988

FIGURE 3



BOREHOLE AND SEIMIC COVERAGE

FIGURE 4



BATHYMETRY

FIGURE 5

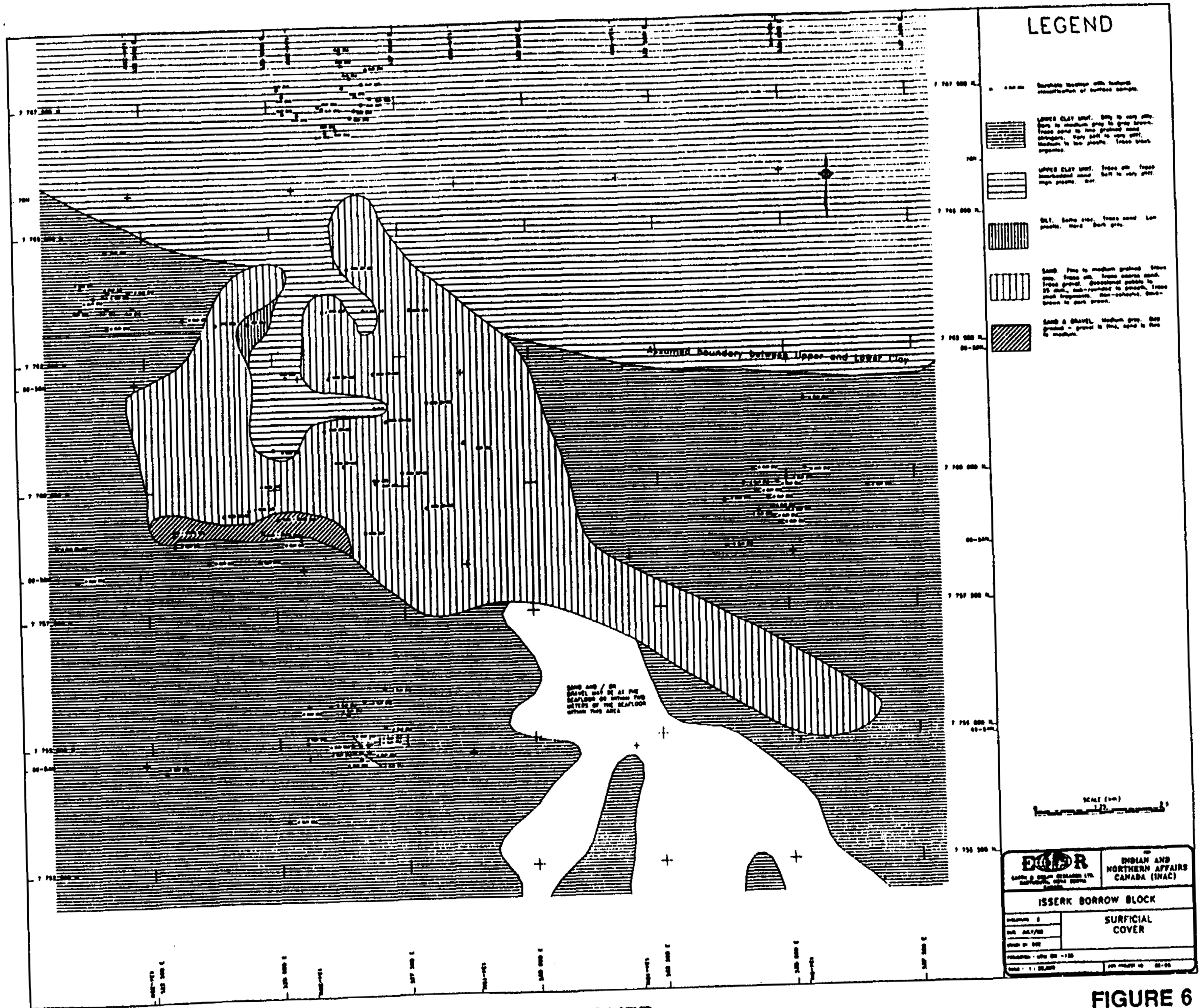
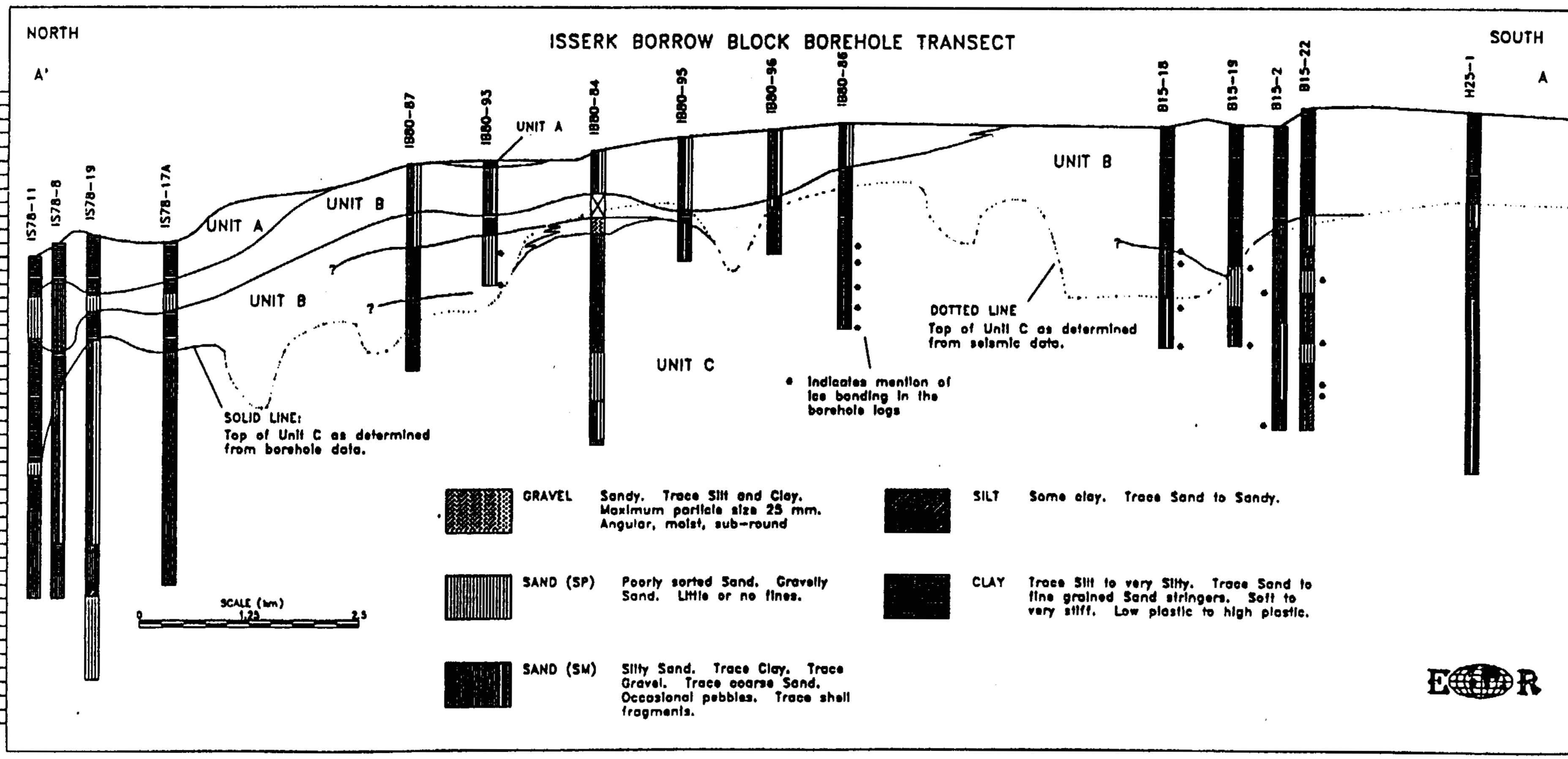


FIGURE 6

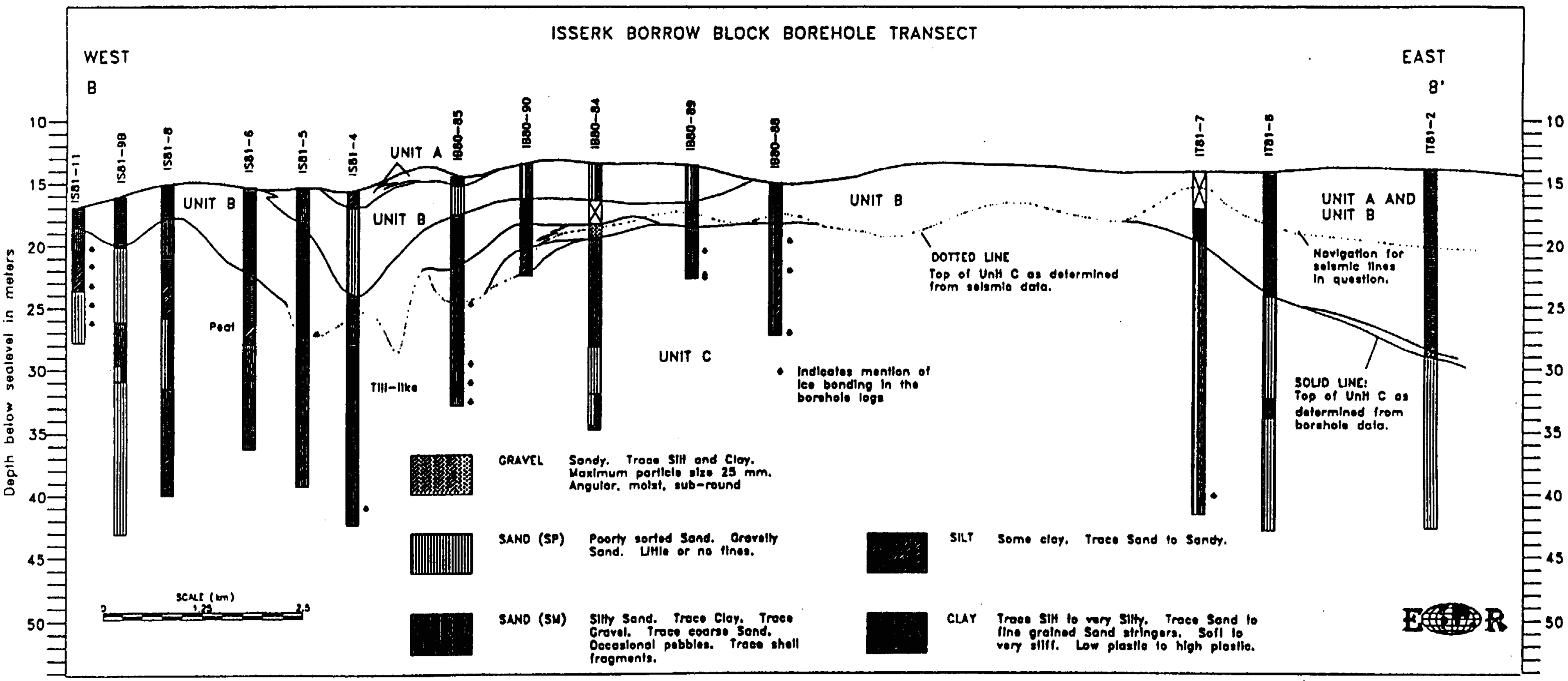
SURFICIAL COVER



ISSERK BORROW BLOCK BOREHOLE TRANSECT - LINE A

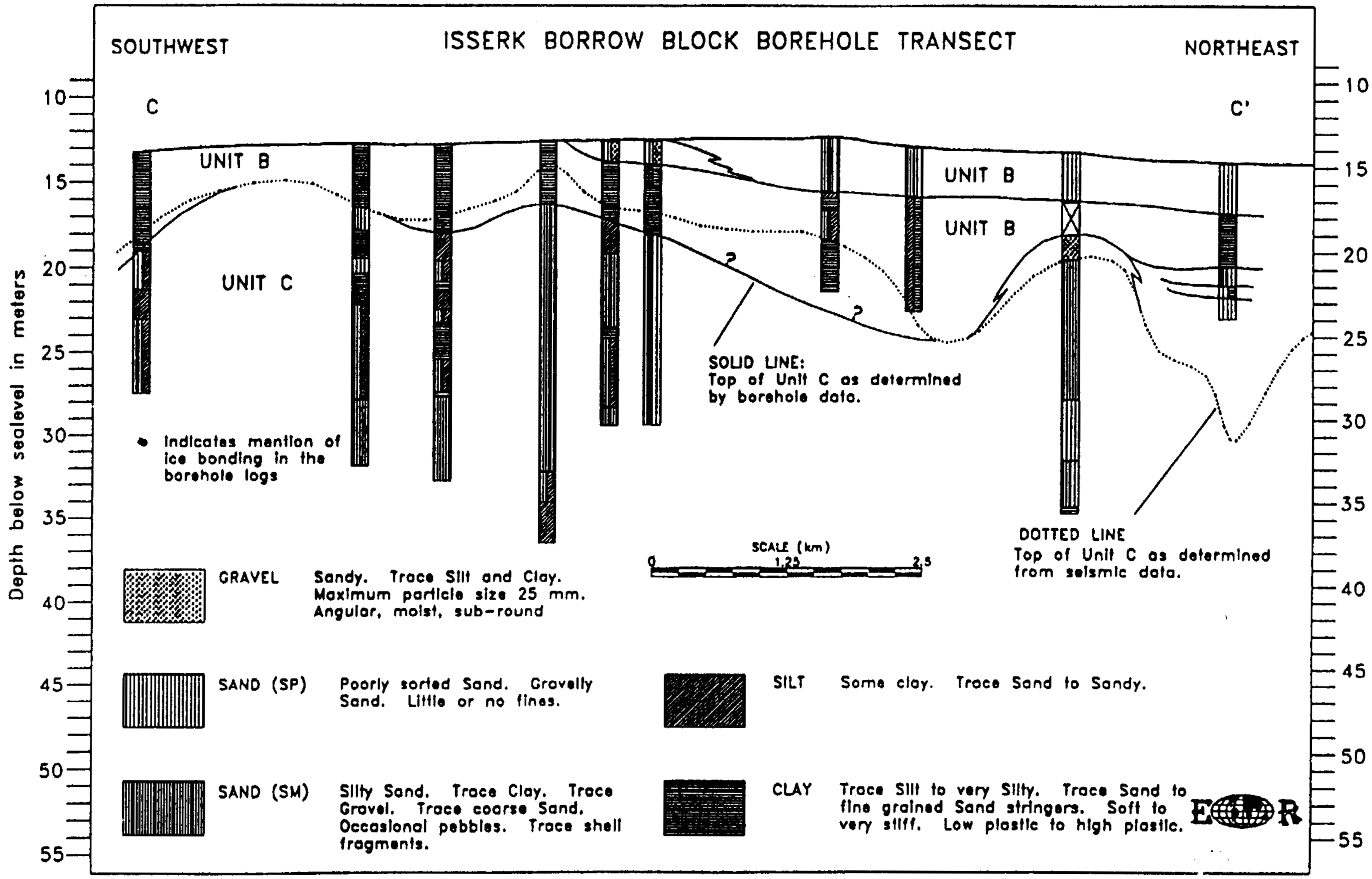
FIGURE 7

ISSERK BORROW BLOCK BOREHOLE TRANSECT - LINE A

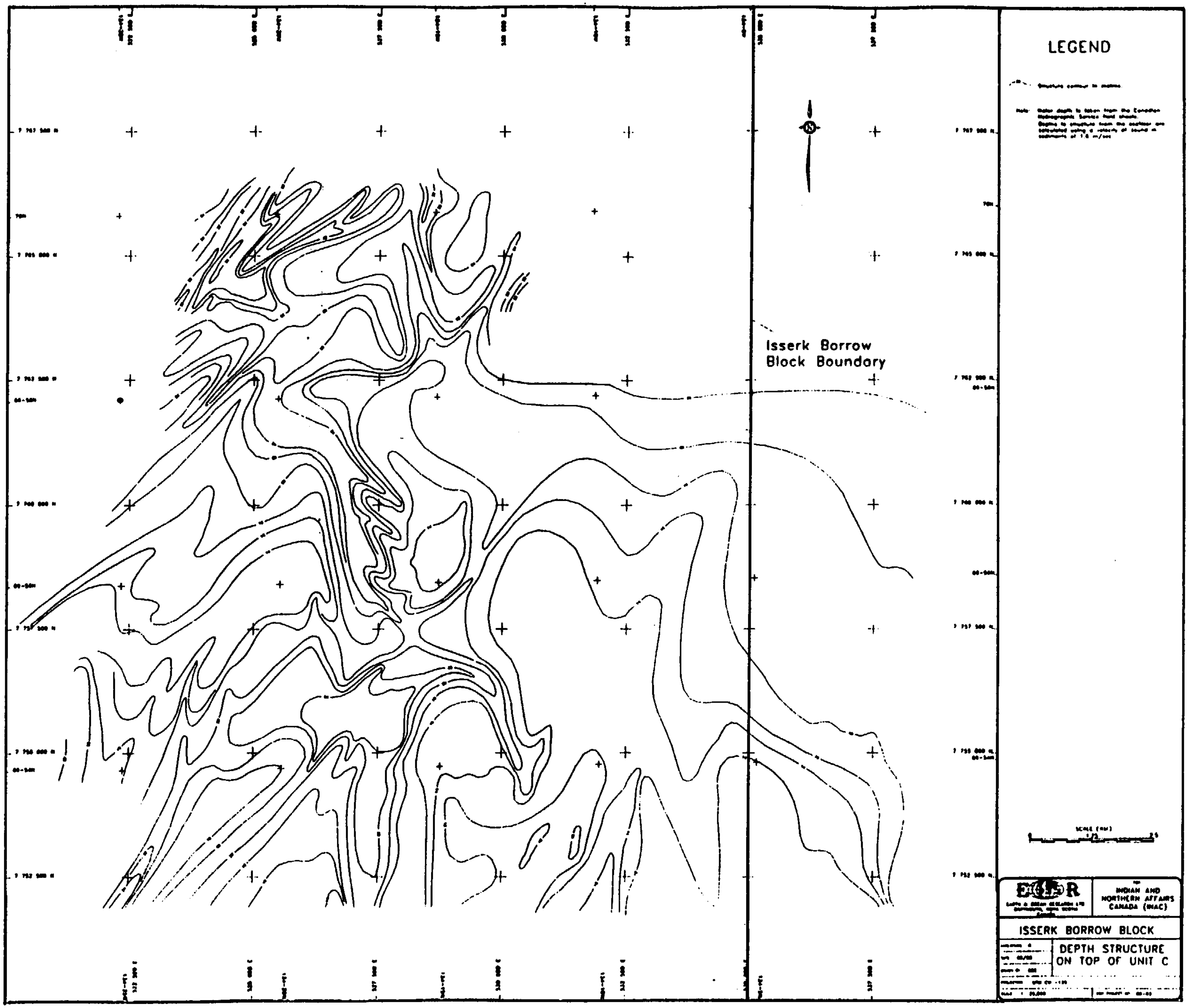


ISSERK BORROW BOLCK BOREHOLE TRANSECT - LINE B

FIGURE 8

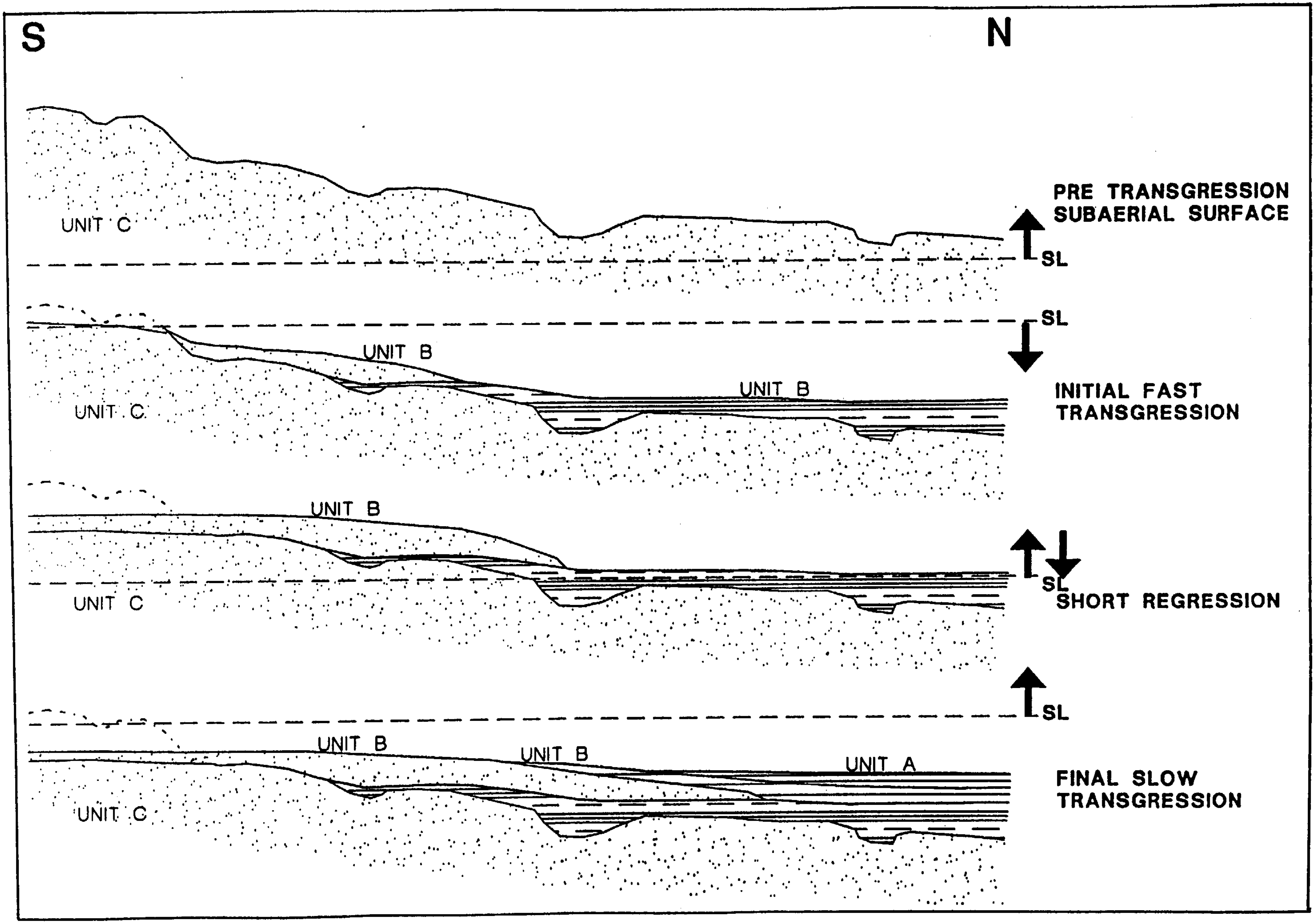


ISSERK BORROW BLOCK BOREHOLE TRANSECT - LINE C **FIGURE 9**



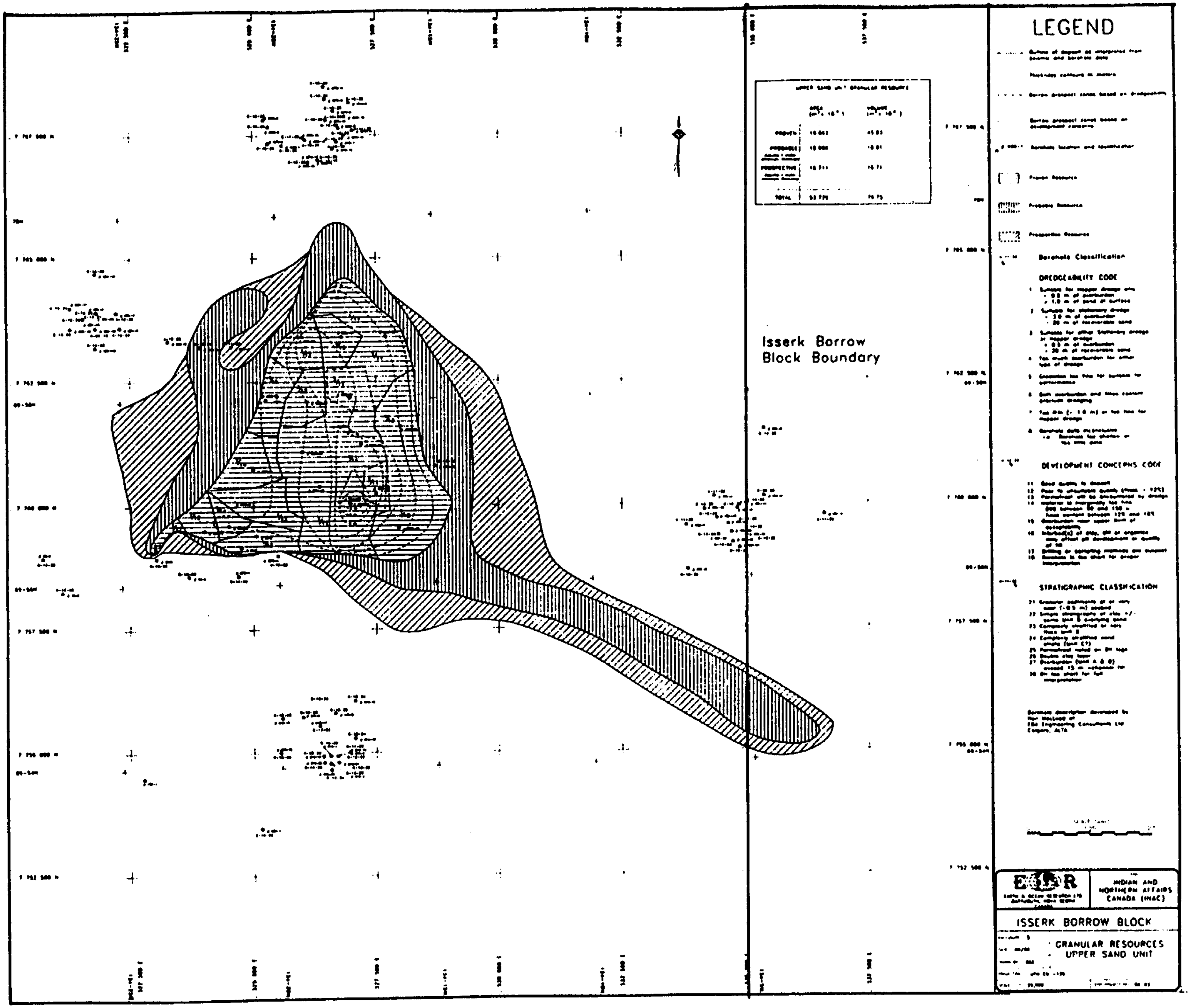
DEPTH STRUCTURE ON TOP OF UNIT C

FIGURE 10

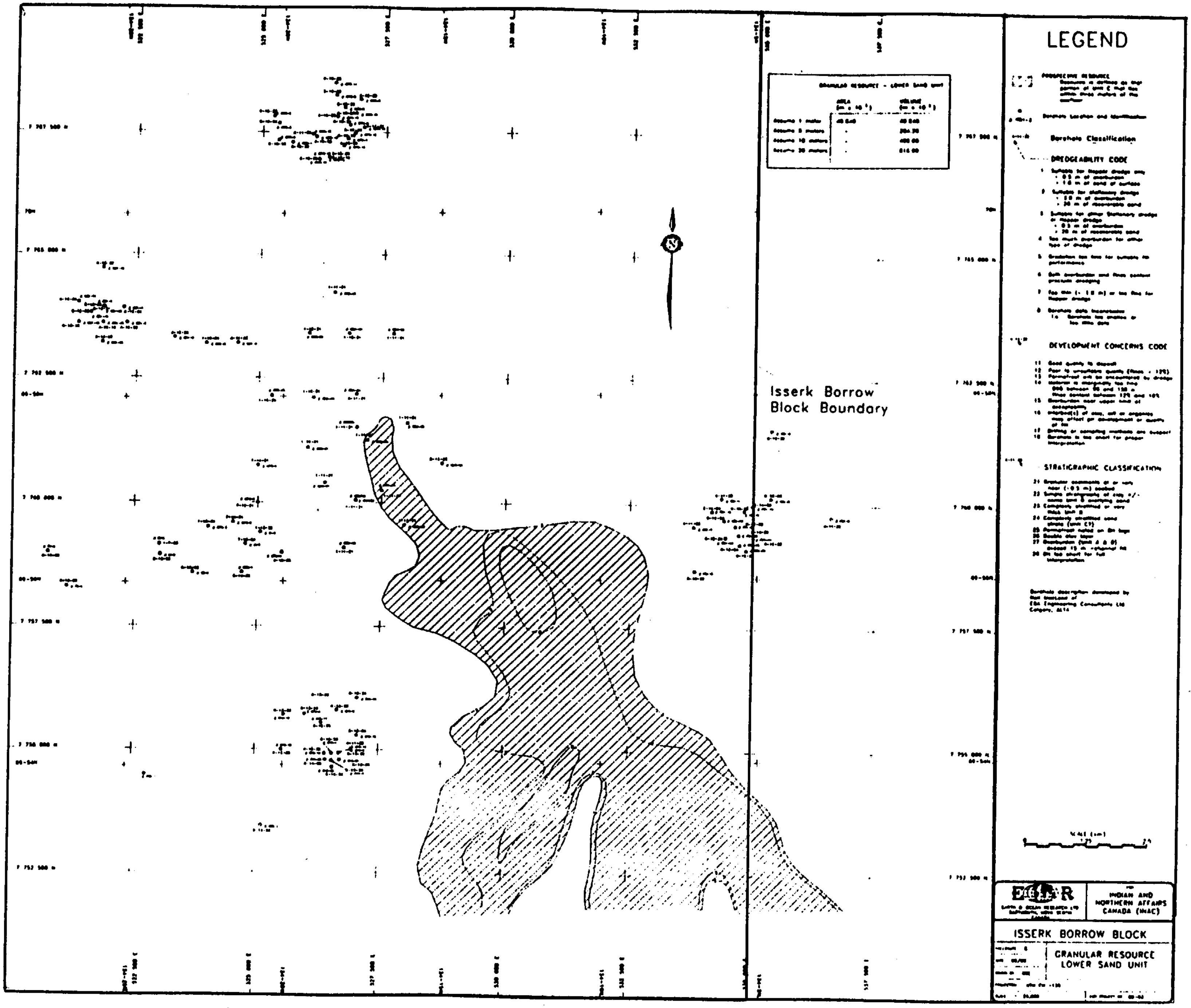


ISSERK DEPOSITIONAL MODEL

FIGURE 11



GRANULAR RESOURCES UPPER SAND UNIT **FIGURE 12**



GRANULAR RESOURCES LOWER SAND UNIT

FIGURE 13

The Erksak Borrow Block
(NOGAP Project A4-21)

Presented By J.F. Lewis
Lewis Geophysical Consulting
Armdale, Nova Scotia

1.0 Introduction

The Erksak Borrow Site study program was one component of a set of three concurrent studies that were initially conducted by Earth & Ocean Research Ltd. through 1987/1988. These studies consisted of a two volume borrow study conducted for DIAND of which Volume 1 is the Isserk borrow site area and Volume 2 is the Erksak borrow site area. The third study was a regional surficial geology program for the south central Beaufort Sea region which was completed for Steve Blasco of AGC. Steve will be discussing these regional geology results in a paper presented at this meeting.

Figure 1 is a map of the Beaufort Sea showing the south central Beaufort geological study area and the two concurrent borrow block study areas. These borrow study reports were completed by EOR under DSS contract AO632-7-5011/ C1ST for Mr. Bob Gowan of DIAND as a part of NOGAP project A4-20.

This paper is specifically in reference to the eastern Erksak study region (Figure 1) which is defined by:

- Northwest: Zone 8; 550,000; 7,800,000 - (70°18'10" 133°40'15").
- Northeast: Zone 8; 609,000; 7,800,000 - (70°17'04" 132°06'15").
- Southeast: Zone 8; 609,000; 7,750,000 - (69°50'12" 132°09'57").
- Southwest: Zone 8; 565,000; 7,750,000 - (69°51'04" 133°18'33").

These co-ordinates describe a quadrilateral that widens to the north. At its closest approach to land, the southern edge of the block lies approximately 9 km to the north of the Tuktoyaktuk Peninsula. The defined area encompasses approximately 2,574 km^2 of the Beaufort Shelf.

The specific purpose of this study has been to evaluate all (or as much as possible) of the geophysical and geotechnical data available within these regions with the primary mandate of attempting to quantize the locations and volumes of proven, probable and prospective granular resources that are present.

All three of the above-referenced studies used a common data base set which was compiled and collated with the intent of using it over the three study programs mentioned above.

2.0 Data Bases

The mandate of these studies was to evaluate all high resolution geophysical and geotechnical data that had been collected in this study area. This consisted of a massive amount of data, though not all of this data could be found and accessed within a reasonable search effort for this study and a resulting more limited, though still significant, data set was actually used.

DIAND had initiated an earlier data compilation contract with McElhanney Services Ltd., which was a library search of the industry geophysical reports to identify the industry geophysical data sets that were originally collected (McElhanney Services Ltd., 1988). A second program with EOR was conducted to compile and digitize the geophysical track data (Peters, 1988) and a third with EBA to identify and compile the geotechnical data bases within the regions (EBA, Isserk 1988a, Erksak 1988b and Central Beaufort 1988c).

The initial tasks of this present study was to locate and copy as much as possible of the geophysical data sets for use within these evaluations. This was carried out over a month long period in Calgary with considerable appreciated help of the respective Beaufort Sea industry operators. A number of the geophysical records couldn't be located and after a reasonable effort, it was decided to go with the data that had been collected.

2.1 Navigation/Geophysical Data Base

The track navigation and geophysical data compilations included the entire area of the south central Beaufort Sea geological study area. Figures 2 and 3 of the section on the Isserk site outlined the entire navigation and geotechnical data bases available for the south central Beaufort study area and will not be repeated hear.

Figure 2 in this paper shows the more limited area of the Erksak borrow site and the geophysical track lines and the location of the geotechnical boreholes available for just this area.

In general, the overall geophysical data set is of good but variable quality. The quality is dependent on weather conditions at the time of collection. Difficult interpretation arises most commonly from real geologic conditions rather than poor collection technique. This is especially evident over the areas of main interest, the borrow sites. Records that display good resolution and are readily interpretable where they cross the channel areas to the east and west of the sites, become congested and the character difficult to determine over the coarser grained materials of the borrow sites.

Of the two main data sources, the boomer and the micro-profiler, the micro-profiler is the more suitable for the resolution of the nature of the surficial cover. The higher frequency envelope of this system makes the signal more susceptible to reflection and attenuation on coarser substrates and is therefore somewhat calibrated to discern sandy material from silty material. In the present application where the determination of coarse material at or very near the seafloor is critical, the profiler's lack of penetration ability in coarser sediments is of less importance than its ability to discriminate between sand and silt/clay. In comparing micro-profiler data to borehole data, it is observed that a strong correlation exists between signal attenuation and reflection character and sediment texture.

The boomer data is more valuable in establishing the seismo-stratigraphy of the study site. The reduced sensitivity to textural changes that limits the usefulness of the tool for discriminating coarse from fine material permits more consistent imaging to greater depths through coarse material. It is also noted that where boomer and borehole correlation is possible, a diagnostic seafloor return is also generated from this source over coarse substrates, though it is less obvious than that of the micro-profiler data.

Appendices 1 and 2 of the text reports (Meagher and Lewis, 1988a and b) describe the McElhanney data base which consisted of a compilation showing the surveys completed and line data originally collected and the results of the data search respectively which describes the listed/found and copied data used for this study. Appendix 2 data base gives the locations of the original data as of April, 1988 and the copied data is currently resident at AGC in their data archives.

2.2 Geotechnical Data Base

The geotechnical data bases were compiled and inserted into ESEBase record form by EBA Engineering Consultants Ltd. for the entire south central Beaufort area. This data base project will be described more fully in a latter paper presented by Rita Olthof of EBA.

Initially, 94 boreholes were identified within the Erksak Borrow Block (EBA, 1988b). While reviewing these data sets, it was discovered that an additional 28 boreholes had been drilled within and just beyond the boundaries of the Erksak Borrow Block which proved useful in this study. These additional boreholes were reported within EBA's final (1988c) report.

The borehole coverage within the entire Erksak Borrow Block is sparse in relation to the overall size of the region. The boreholes tend to be clustered into 4 or 5 main groups which were drilled for exploration island sites and detailed dredging evaluations at specific locations. The coverage in these detailed regions is probably adequate for the detailed local assessment of borrow quality and quantity; however, the detailed re-evaluation of these very limited areas has not been feasible within the context of this regional study.

Mr. Neil MacLeod of EBA, via a sub-contract to this study, assisted in developing a coding system for the sediments encountered within the boreholes which takes into account the sand and gravel quality and current dredging requirements and equipment restrictions of the Beaufort Sea operators. The coding system has been used in the figures describing the borrow prospects and has been used for evaluation of the borrow potential of the respective sites when boreholes are available. This coding system is reproduced on the maps of the detailed borrow prospects discussed later. For detailed discussions, refer to Meagher and Lewis (1988a and b).

3.0 Site Descriptions

Throughout this section, discussion and interpretation is restricted to the region of the Erksak Borrow Block. It is aimed primarily at the surficial physiography and shallow sedimentary section for the sole purpose of granular resource borrow evaluation. These restrictions encompass Units A, B and the top section of Unit C which were initially defined in M.J. O'Connor's 1980 report. In order to facilitate the detailed discussion of this region, the physiography of the area has been examined in detail and additional physiographic names beyond those presented by O'Connor (1982a) have been used to describe the bathymetric and shallow sub-surface features within the area. These names are presented as informal names and are used primarily to aid the reader in following the detailed discussions within the original text report. Sedimentary Unit names referred to within this talk follow the O'Connor (1980) terminology conventions.

The interpretations have been directed specifically at the location and identification of coarser grained borrow materials and therefore does not follow the standard convention of most regional geologic descriptions. Thus sub-surface maps generated are based on seismo-lithologic interpretations directed at delineating coarse materials and use ground-truth borehole evidence where possible. These maps are specifically <u>not</u> time stratigraphic interpretations which would be the norm for geological interpretation procedures.

3.1 Bathymetry

Figure 3 is a contour map of the bathymetric contours over the Erksak site at a 1 m contour interval within regions where the CHS data was adequate and at a 2 m interval where the data was sparse. The high definition information (highly crenulated 1 m contours) has been developed by a careful re-contouring of Canadian Hydrographic Service (CHS) field sheet WA-10176 (water depth postings) which was resurveyed by CHS in 1986. The more smoothed contour area portions of the map have been constructed from the Natural Resource Series bathymetric map for the area. This latter bathymetric map was used to extend portions of the east and north zones of the site where the detailed newer field sheets were not available at the time of writing. The significant decrease in the crenulation of the contours, apparent on the produced map in these areas, is an artifact of this procedure and is not due to real changes in the seafloor micro-topography.

The topography of the site is developed on a regional north-northwestward sloping plane. A minimum depth of 6 m is recorded at the extreme southeast corner of the site and a maximum depth of 54 m is noted at the extreme northwest corner. Superimposed on this plane are a number of distinct topographic features of varying scale that impart an irregularity to this surface. The larger topographic features are the physiographic regions; Tingmiark Plain, Kugmallit Channel and Niglik Channels, outlined and described by O'Connor (1982a). Local variations in the bathymetry and the underlying paleo-surface that influence and control the bathymetry permits the subdivision of the Tingmiark Plain into smaller component regions. These divisions and subdivisions are outlined on Figure 3. For ease of reference, the subdivisions are given informal names intended for use within the context of this report only.

The Tingmiark Plain has been subdivided into the West Erksak High, Erksak Channel, Uviluk High and Uviluk Channel. The West Erksak High is further divisible into the Erksak Crest, Kogyuk Terrace and Ukalerk Slope. The southwest corner of the map area is occupied by the James Shoal Extension. The Kugmallit Channel and Niglik Channels are not subdivided.

3.2 Surficial Cover

The distribution of the surficial sediment type exposed on the seabed within the Erksak Borrow Block is presented in Figure 4. The mapping of the surficial cover is based primarily on an examination of the seismic data, particularly the micro-profiler records, validated wherever possible with visual descriptions of seabed samples. Where the seismically defined textural class boundary differs from that derived from the sample control, it is shown with a dashed line. Seismic data is used exclusively in the northwest and north where there are no boreholes and bathymetric field sheet coverage is not available.

Textural information from the tops of the 122 boreholes has been augmented by 164 seabed samples collected by the Canadian Hydrographic Service during the 1986 field season. CHS collected these seabed samples using a small grab sampler on a 5 km grid over the area covered by Field Sheet WA 10176. Where shoal examinations were carried out, the seabed texture was determined using a smaller armed lead line sampling device. Size analysis are not routinely performed on grab samples by the CHS and the samples are routinely discarded at sea after examination. The textures derived from the borehole logs are primarily based on visual description; though in some cases, they are supported by lab testing. The surficial cover map is, therefore, restricted to broad textural classification.

The distribution of surficial sediments is topographically controlled. Sand and sand-dominant material is restricted to shoals, although not all shoals are sandy. The Kugmallit Channel and Erksak Channel are uniformly fine grained, with exceptions at the Amerk O-09 artificial island site and a sand sample taken from a small shoal located 4 km to the northeast of the Amerk site. This shoal is anomalous in that it rises 6 m to a water depth of 22 m from an otherwise low relief plain and consists of sand where the surrounding area consists of soft clay. The feature has the appearance of an artificial island though the CHS field sheet records the location of artificial islands and this shoal is not noted as such.

Over the West Erksak High the sediment distribution is more varied, but still related to the local relief with sand or muddy sand recorded over the ridges of the Erksak Crest and sandy mud or mud noted within the depressions. The outline of the distribution of sand at the seafloor as determined from the seismic data is displayed on the map with a dotted line. A comparison of this outline with the distribution mapped from the CHS samples shows that the fine cover is more extensive than the seismics alone would suggest. This is most likely the result of a veneer of fine material resting on the sand substrate. The thickness of this veneer would not exceed about 30 cm or it would be visible on the micro-profiler records.

Seismic and borehole data over the Uviluk High indicate that sand covers most of the surface with mud occupying two northwest-southeast trending depressions.

The southern shoreward portion of the area over the James Shoal Extension is generally covered by soft clay or mud. A sand sample is noted next to the Alerk P-23 artificial island and a second sand sample is recorded 3 km to the east on the flank of the main shoal of the James Shoal Extension. The CHS sample grid did not sample the top of the main shoal, but it is surmised that the sand sample is representative of the surficial cover of this feature.

The fine material surrounding the coarse deposits consist uniformly of inorganic clays with very occasional black organic streaks. They are generally low to medium plastic with a water content that varies from about 20% to 45% (Unit B type clays). The clays also vary from soft to very stiff. Trace amounts of sand in fine laminations are noted in several samples as well as trace amounts of silt and shells.

3.3 Subsurface Geology

The sub-surface geology within the site can be described within the framework of O'Connor's stratigraphic model for the Beaufort shelf (Units A, B and C). However, the design of this program has been aimed specifically at "Borrow Materials" and as was noted at the Isserk Site, a very complex relationship can exist with regards to Units B and C as far as coarser grained sands materials distribution is concerned. As there is no reason to assume a different geological scenario for the Erksak site and since this much larger region does not have the density of borehole control that was available at Isserk, a tact of defining the distribution of the top of potential borrow material (sands) was taken as opposed to attempting to map the most recent regional unconformity (top of Unit C). This concept worked well with the micro-profiler and boomer data sets as in many instances, the actual top of the unconformity surface could not be acoustically mapped beneath sandbars and shoals composed of the re-worked Unit B materials. No attempt to differentiate upper and lower sand prospects on the maps of this study has been made as the added complexity would not have been viable on such a large and complex area. This distinction has to be left to more detailed site specific borrow target studies.

With this mandate in mind, the seismic and borehole data sets were combined to produce a depth structure map of the Top of Prospective Sands within the site area (Figure 5). This surface is not a time stratigraphic horizon, but is a composite of, in many cases, overlapping reflecting horizons of laterally discontinuous higher amplitude reflections interpreted to be the top of shallow sands or prospective borrow materials within the area. While these horizons are not time synchronous, when taken together, they form a morphological pattern that suggests a depositional system acting over a short period of time which is likely associated with a high energy shallow water near shore active erosion and redistribution environment. This environment has migrated shoreward with time associated with the most recent marine transgression of the area.

Figure 6 is an isopach contour representation of the soft surficial sediments overlying these prospective sands. This information is necessary for defining regions of prospective resource because of the limiting constraint of having a maximum of 3 m of overlying material that might have to be stripped away to get at the resource. Note from the structure map that the definitions of the supplementary physiographic regions are much more distinct where they were quite muted though still evident on the bathymetric map presented earlier.

These maps indicate that the physiographic highs typically have a thin or absent soft sediment accumulation and irregular patterns of distribution. Within the physiographic lows, the accumulations of soft materials are controlled by the well developed topography of the underlying surface. The Kugmallit Channel shows thick accumulations (up to 24 m) of soft materials in the south and thinning toward the north (between 1 and 11 m). A similar pattern is noted in the Erksak Channel. In the east, in the Uviluk Channel, accumulations are not as well defined due to the general lack of data though range from 4 to 7 m in thickness.

3.4 Depositional Summary

Based on the geophysical and sampling data, a tentative depositional summary of the upper 20 m of the sedimentary column has been developed. The Beaufort sea shallow geological sequence consists of a number of repeated cycles of marine incursion separated by periods of sub-aerial exposure related to glacially induced low stands of sea level. This sequence has been built on top of a continued regional basin subsidence in the region and there are believed to be approximately six or more cycles preserved within the Quaternary section which constitutes the upper 400 to 600 m of sedimentary section in the central Beaufort area. This study concentrates on the upper 20 m of this section which represents the sub-aerially exposed surface developed prior to the most recent marine incursion of the area and the post-transgression deposited sediments. These sediments represent the accumulated deposition over approximately the last 12,000 to 14,000 years. During this period, average sedimentation rates of up to 3 to 4 m per 1,000 years during the early part of the cycle have occurred assuming age dating within the sections have been accurate.

The developmental history of this site essentially consisted of the very fast deposition of Unit C sands as a glacial outwash and braided stream system which existed during the last glaciation from about 14 - 18 ka until inundation by the re-advancing seas. These periglacial coarser grained materials were sub-aerially exposed and subject to significant permafrost aggradation prior to inundation. The 11 boreholes in the area, which fully penetrate this unit, indicate that Unit C is from 35 - 50 m thick.

The region was inundated by the advancing seas during approximately 8,000 (off-shore) to about 3,000 (near shore) years before present based on the current water depths and the presently understood Relative Sea Level curves for the area (Hill et.al., 1985).

The physiographic regions, as defined in this study, are believed to outline the last sub-aerially exposed topographic conditions prior to inundation. The Erksak High, James Shoal Extension and Uviluk High represented topographic promontories that were bounded by the Uviluk, Erksak and Kugmallit Channels. The channels were likely existent some time prior to inundation though because of the excessive down-cutting in the Kugmallit Channel, it is speculated that the Erksak and possibly the Uviluk Channels were abandoned some time prior to inundation. Thus, the sand bar/channel island features noted in the Erksak channel are interpreted to be riverine and not transgressive in origin.

The deeper Kugmallit Channel was the first region to be inundated and as sea levels rose, the Erksak Channel would have been inundated approximately coincident with the Ukalerk Slope. Since the remnant channel and knoll topography is still preserved on the Ukalerk Slope, it is presumed this region was inundated rapidly. The broader contours of the Kogyuk Terrace imply that sea level rise slowed and the region was cut back further by shoreline retreat associated with the breaker zone. This factor suggests the region might be richer in concentrated gravels than other areas though this is not confirmed at this time. The last areas to be inundated would have been the upland Erksak Crest, James Shoal Extension and the Uviluk High.

Both prior to and during inundation of the higher areas, sub-aerial erosion would have concentrated the coarser fraction materials along the edges of these highs. This is evident on the seismic records over the edges of both the Kugmallit and Erksak Channels. Just after inundation in any particular region, the local areas would have undergone a high energy environment which transported the fine materials off-shore while the coarser materials would remain virtually in place. These remnant materials formed the local bars and foreset bedded coarser materials of the surficial Unit B sediments which are quite variable throughout the area. As transgression continued and the regions passed below wave base, a transition to finer sediment deposition occurred with eventual deposition of the finer facies Unit B clays and finally the Unit A clays. Areas where sands are still exposed at the seabed are presumably still under the influence of wave base erosion and winnowing of the finer sediments, though at present, most of the Erksak block would only be significantly affected during major storm events.

4.0 Granular Resource Model and Evaluations - Distribution

Figure 7 is a map of the granular resource prospects determined within the Erksak Borrow Block area. The tight horizontal hatching represents areas defined as proven resource zones based on the borehole sampling and the seismic information and the broader vertical hatching represent areas of prospective resource based on seismic evidence and some limited surface and borehole samples.

The outer boundaries of these prospective zones have been defined by the 3 m contours of the soft surficial sediment isopach map presented in Figure 6, as this is the present day economic limitation of conventional dredging equipment when overburden stripping is required. Areas with a zero-cover isopach might be considered higher priority from a site development point of view.

Because of the large extent of the region, the potential borrow sites have been numbered from 1 to 33. In the large areas of virtually continuous accessible resource on the West Erksak High and the Uviluk High, a subdivision has been made based on the localized areas of the zero-cover isopaches. Where possible, the boundaries between individual sites follow the maximum thickness of soft sediment cover. Within the Erksak Channel and the Kugmallit Channel, most of the resources have at least 1 m of soft cover and therefore, the boundaries of the prospective resource is defined by the 3 m isopach contours. In addition to these prospects, two prospects on the James Shoal Extension have been defined by borehole and sample information only.

Table 1 indicates the surface areas of each of the prospects and is broken down into the area between each set of overburden isopach contours out to the 3 m maximum. It should be noted that some of the identified prospects, or at least portions of them, have been concluded to be marginal in quality as far as their suitability of construction materials are concerned. Given the limited ground truthing available at this time, they are included within the prospective volume estimates pending further direct sampling evaluations.

Prospects 1 to 12 are located on the West Erksak High, 13 to 20 within the Erksak Channel, 21 and 22 on the Uviluk High, 23 to 27 on James Shoal Extension and 31 to 33 within the Kugmallit Channel. Prospects 28 to 30 are on the James Shoal Extension, but have been defined by borehole and grab sampling only.

From the table summary, 364 km^2 show no or virtually no surficial cover (30 cm or less from the acoustics), 146.8 km^2 lie between the 0 and 1 m contours, 294.1 km^2 lie between the 1 and 2 m contours and 192.2 km^2 lie between the 2 and 3 m contours. In total, 997 km^2 of the total 2,574 km^2 Erksak Borrow Block area are considered to be prospective granular resource areas.

Within this thousand square kilometres, a smaller sub-set of area has been designated as proven reserves based on the borehole and sample control which has allowed us to put a quality factor on the sediment resources. These tightly hatched areas on Figure 7 have been based on an arbitrary assumption that the borehole data represents a region within a one-half kilometre radius of the boreholes. Thus, a sub-prospect is defined either by a 1 km diameter circle or a perimeter defined by a grouping of these circles and also limited by the 3 m overburden contour when appropriate. These sub-prospects have been given designations such as "p4b" where the "p" indicate a proven resource, the "4" indicates that it is within prospective area #4 and the "b" is an alpha designator identifier for that particular sub-prospect.

No attempt has been made on the plot of Figure 7 to spatially define the probable resources within the area as limitations on the seismic coverage would not allow a clear definition that could be mapped. Within the following volume of resource discussion, a summary attempt has been made to delineate the probable reserves available within the prospective zones.

5.0 Resource Prospect Granular Volume Estimates

5.1 Proven

Of the 33 prospects outlined above, only 8 have been sampled by borehole testing with sufficient detailed analysis to allow designation of the sediments as a proven reserve. Table 2 summarizes the proven sub-prospects, identifies the borehole control and assigns a short summary quality evaluation to each. In reviewing the boreholes, an estimate of the volume of useable borrow material has been made either on the basis of sampling depths of the boreholes (limit of sample depth) or on layering within the sediments which would indicate that fines are below and it would not be worth deeper dredging. Their dredgeability in terms of dredge type has also been indicated. This is based primarily on the overburden cover and the granular materials.

In total, there are 60.3 km^2 of proven resource areas defined and these areas provide a relatively firm potential for 720 million cubic metres of recoverable resource materials within the Erksak Borrow Block.

Within the original report, there are detailed discussions on each of these sub-prospects which cannot be discussed here.

5.2 Prospective

Table 3 combines Table 1 with an estimated volume calculation of granular resource that is dredgeable by various dredging techniques that are currently in use. This prospective resource estimate does not take into account a quality factor since only a few of the sites have been tested by borehole sampling.

The breakdown of this table assumes Hopper Trailer dredges that can mine the surface sands to a depth of 2 m below the seabed and are limited to 1 m or less of soft surficial sediment cover for stripping purposes. In this instance, the potential resource recoverable is calculated in the eighth and ninth columns with the total resource recoverable by this method in column ten. Assuming a stationary suction dredge which can strip off up to 3 m of overburden and potentially mine to a depth of 20 m below the seabed, total prospective reserves for depths of 5 and 20 m sub-seabed are computed. These areas and volumes include the proven reserve areas of the previous section.

With these processes, a volume of 948 million cubic metres is potentially recoverable by Hopper Trailer Dredge and if Stationary Suction Dredges are used, a total region potential of 18.9 billion cubic metres of prospective resource are possible.

5.3 Probable

The above two sections have provided estimates of the proven and prospective resources within the Erksak Borrow Block. An estimation of the probable proportion of useable reserve from the prospective total above is attempted here. Probable reserve is defined a sands and gravels whose existence and quality has been inferred on the basis of limited ground truthing information and/or several types of indirect evidence including side scan sonar, shallow high resolution seismic, echo sounding and/or bathymetric and/or geologic considerations. These estimates are based on an understanding of the proven reserves determined by boreholes and a comparison with the seismically mapped prospective zones to provide a "best estimate" of probable resource for planning purposes.

Within the Erksak borrow block there are basically three types of prospective granular resource deposits which have been outlined by the seismic mapping program. The upland regions of the West Erksak High, the Uviluk High and the James Shoal Extension contain two basic reserve types. The bar and island features within the Kugmallit and Erksak Channels are the third type. On the upland regions, the reserve consists of exposed remnants of Unit C sand materials as the basal material and of the re-worked coarse materials which are noted as migrational ridges and progradational wedges that have extended the upland regions into the lower lying channels. The re-worked materials may represent Unit C materials if they had been deposited prior to transgression within a sub-aerial or riverine environment or lower facies of Unit B materials if deposited in the near shore breaker zone or current controlled deposition associated with the last transgression of the sea across the region.

The available data have been reviewed on the basis of probability of occurrence of unacceptable sediment layers or limiting zones within each deposit. Although it has not been possible to map, in detail, specific features which indicate a significant probability of containing higher quality materials, volumes have therefore been estimated by applying an interpretive reduction factor to the estimates of prospective resources. Table 4 summarizes these estimates of probable resources in the Erksak Block.

Utilizing these quality factors, the probable granular resource estimate for the Erksak Borrow block reduces to 7.4 billion cubic metres from the almost 19 billion cubic metre prospective reserve. In particular, the area of the James Shoal Extension has been significantly restricted in these evaluations because of the paucity of data over the feature. Therefore, the larger area of the entire feature has been excluded from the tables presented here. If it were to be included, an additional 4 to 6 billion cubic metres might be added within the prospective category of borrow reserve of which 2 to 3 billion might be considered probable.

6.0 Conclusions

The 2,574 km^2 area of the Erksak Borrow Block located in the south central Beaufort Sea continental shelf contains significant quantities of proven, prospective and probable fine to medium grained sandy granular resource materials. The analysis of this region did not indicate any significant concentrations of coarser grained sand or gravel materials, though numerous trace indications were noted from the borehole records.

The region consists of a drowned upland region composed primarily of medium to fine grained sands (Unit C) which had been dissected by a series of channels prior to inundation by the sea within the last 3,000 to 10,000 years. During this time range, the low lying areas of the Kugmallit Channel were inundated toward the southern block area at approximately the same time as the northern upland areas of the prospect were just commencing the transgression process. During this period, the shallower regions of the possibly more ancient Erksak channel system were partially inundated and at some point, left the Uviluk High and the West Erksak High as near shore island features while the James Shoal

Extension area was a promontory point, either attached to the mainland or itself cut off from the mainland by the Uviluk/Niglik Channel system further to the east. All through this process, the upland regions were being eroded both sub-aerially and by the near shore breaker zone and wave base effects of the advancing seas. As sea level rose further, the upland regions were eventually inundated by the sea and were modified by the transgressive erosion activities as the sea progressed through the high energy breaker and wave base erosion zones toward the present day deeper water conditions.

Throughout the transgression process, the surficial sediments of the upland areas were re-worked to form a transgression unconformity with the finer components winnowed out and transported to quiescent regions for re-deposition as Unit B or Unit A materials. The coarser grained sands tended to be transported shorter distances, if at all and in some cases, formed progradational wedges along the edges of the highs or were localized into sand ridges or sand bar features when conditions were correct. These materials form a portion of the granular resource in the region while the main body of the resource is composed of the deeper Unit C materials.

Similar processes were at play prior to marine inundation within the sub-aerial channels of the study area. These process were river and/or wind dominated and contributed to the progradational wedges seen adjacent to the higher regions and formed the river bar features noted within the Erksak Channel and the sub-channels noted within the eastern portion of the Kugmallit Channel. These sedimentary features are technically attached to Unit C; however, in many cases, the distinction between this unit and the higher energy transgressive facies of Unit B are not distinguishable from the seismic or borehole data.

As regions of the borrow site passed through these active zones, accumulations of finer grained sediments began to predominate. These accumulations first began in the deeper water zones and topographic lows and progressed higher on the upland areas as the transgression continued to its present condition.

The original pre-transgression topography and the effects of the transgression process have resulted in the present day conditions within the Erksak Borrow Block. The distribution of the potential borrow materials are concentrated on the upland areas, though significant recoverable materials are available within the Erksak Channel. Much of the eastern portion of the site has not been adequately evaluated within this study as little seismic or borehole data was available. However, bathymetric studies suggest that this area is likely to be relatively silt or clay covered which reduces its attraction.

The geophysical and geotechnical data utilized through this survey did indicate the presence of shallow sub-seabed permafrost in the area. It is, however, of the Hummocky type APF and relatively randomly distributed. In most cases, it is greater than 10 m below the seabed. As a result this hazard to dredging will locally be significant to the utilization of deep stationary dredging methods. On the regional basis, however, it is felt that permafrost does not seriously degrade the assessment of the viable resource in the area.

Analysis of the geophysical and geotechnical data base has shown that almost 720 million cubic metres of relatively fine grained granular resource have been proven. Within the entire Borrow Block, the geophysical data have outlined a maximum potential of some 19 billion cubic metres of prospective borrow material of which about 950 million cubic metres could potentially be recovered by Hopper Trailer dredge (5%). Of this prospective recoverable material, it is estimated that something in the order of 7.4 billion cubic metres would be in the category of probable recoverable resource when quality factors and an estimation of the variability of sub-surface conditions are taken into account. It is noted here that the entire James Shoal Extension physiographic region may be considered as a prospective area, but was not included in these volume estimates because of the paucity of available data in this area.

These estimations are based primarily on the relatively large, but variously distributed geophysical and geotechnical data sets that are presently available for the area. It is noted here that these data sets are not sufficient to define an actual borrow utilization development program and further detailed site survey and borehole quality assessment programs are required within any local area prior to commencing any actual dredging activities.

Table 1
Areas of Granular Resource Prospects - Erksak

Site No.	Water Depth Range (m)	AREA (km^2) Overburden Cover Thickness				
		0 m	0-1 m	1-2 m	2-3 m	Total
West Erksak						
1	15-26	217.0	42.1	47.8	21.8	328.7
2	26-28	16.8	10.2	16.4	8.4	51.8
3	23-25	10.2	5.8	10.9	5.6	32.5
4	26-34	32.1	13.4	19.6	11.7	76.8
5	36-48	2.1	2.0	7.2	1.7	13.0
6	34-36	2.9	7.2	5.7	2.0	17.8
7	36-38	1.8	3.9	7.8	10.6	24.1

Table 1
Areas of Granular Resource Prospects - Erksak

Site No.	Water Depth Range (m)	AREA (km^2)				
		Overburden Cover Thickness				
		0 m	0-1 m	1-2 m	2-3 m	Total
West Erksak Channel (Continued)						
8	37-38	1.2	1.6	7.7	2.7	13.2
9	32-35	5.7	8.7	18.0	6.7	39.1
10	32-34	0.7	2.4	4.6	2.0	9.7
11	28-33	1.6	8.6	14.7	6.9	31.8
12	24-29	8.9	21.0	14.3	15.5	59.7
Erksak Channel						
13	30-35	-	1.1	13.5	7.8	22.4
14	30-33	-	-	7.3	7.2	14.5
15	28-31	-	-	7.0	5.4	12.4
16	14-19	-	3.3	8.4	15.6	27.3
17	20-33	2.2	4.4	30.9	22.5	60.0
18	16-23	-	-	20.4	6.2	26.6
19	15-19	-	-	-	6.5	6.5
20	14-20	-	-	9.5	10.9	20.4
Uviluk High						
21	26-30	23.0	2.8	4.8	4.8	35.4
22	30-32	16.6	5.5	5.5	4.5	32.1
James Shoal Extension						
23	26-28	-	1.1	1.4	0.7	3.2
24	27-30	-	1.1	8.4	1.6	11.1
25	28-30	-	-	0.2	0.3	0.5
26	28-30	-	-	0.1	0.3	0.4
27	28-30	-	-	0.3	0.6	0.9
JSE (boreholes only)						
28	20-22	0.8	-	-	-	0.8
29	8-11	5.3	-	-	-	5.3
30	8-11	15.0	-	-	-	15.0
Kugmallit Channel						
31	46-51	-	0.6	1.7	0.7	3.0
32	50	-	-	-	0.3	0.3
33	50-55	-	-	-	0.8	0.8
TOTAL AREAS		363.9	146.8	294.1	192.2	997.0

Table 2
Proven Granular Resource Estimates

Prospect I.D.	Water Depth (m)	Area X10^{6}m^2	Boreholes I.D. Reference Nos.	Quality Comments	Dredgeability	Volume X10^{6}m^3
p1a	14-17	8.57	EK84S01-EK84S07, EK84S1A-EK84S7A, UB80-40, UB80-41	SP-SM trace silt & clay	Variable	85
p1b	20-23	7.06	UB82S04, S21, S22, S23, S24, S25, S3A, UB82V05, V06, V20, V21, SUB8301	SM to SP, some silt layers	Hop & Sta	141
p1c	23-25	12.67	BTN1-1, -4, -5, -6, -7, -8, -9, UB80-38, UB82S26, UB82V18, V19	SM, some silt clay layers	Hop & Sta & Possible Sta	123
p1d	23-24	0.79	UB80-39	SM to SP	Hop & Sta	16
p1e	25-26	0.44	KBVC03	SP, SP-SM loose S & org to 2.8 m	Hop & ?Sta	8
p1f	26	1.52	KBBH1-KBBH5	SM to SP, clean trace gravel	Sta	30
p1g	24	0.79	SUB83S01	SM to SP	Sta & Hop	16
p1h	25-26	0.79	NT82S01	SP, clay @ 5.5 m peat @ 6.5	Hop	4.3
p1i	22-23	0.79	UB82S01, S02	SP to 10 m trace silt	Hop & Sta	8
p1j	26-27	0.44	UB80-45	SP, SP-SM 2.5 m clay, sand to 10.5 m	n/a	0
p2a	26-28	3.36	UB82V09-B82V14	SP occ SM trace silt	Hop to Sta	27
p4a	28-30	2.77	BTN1-2, -13, -14	SP - SC some silt & clay sampled to 5 m	Hop ?Sta	14
p4b	29	0.79	UB82V07, V08	Excessive fines marginal	n/a	0
p4c	26	1.17	K682S02, S03	SP, SP-SM trace silt & gravel	Sta	22
p14a	32	0.91	NU82S01, S03	SM to ML too much fines	n/a	0
p18a	21-22	0.085	UB80-42	SM only sampled to 7 m	Sta	0.4
p21a	26-28	0.79	UV80-54	SM with some silts sampled to 9 m	Hop & Sta	7
p22a	29-32	10.54	FUVI1, 1A, UV80-46 TO -52, UV80-55 TO -58	SP-SM trace silt, clay & gravel	Hop & Sta Localized	105
p28a	22	0.79	UB80-44	SP-SM some thin silt/clay layers	Sta (to 14 m)	10
p29a	8-12	5.27	AL80-1 to -18	SP, SP-SM some thin silt	Hop & Sta Localized	100
Totals		**60.335 km^2**		**Total Proven Volume**		**720.7**

Table 3
Prospective Granular Resource Volume Estimates

Borrow Site	WD m Range	Area: 0 m cont km²	Area: 0-1 m cont km²	Area: 1-2 m cont km²	Area: 2-3 m cont km²	Under 0 m	Volume Estimates Times 10^6 m^3: Hopper Dredge to 2 m Depth: Under 0-1 m	Total Hopper	Stationary Suction to 3 m of Cover: 5 m Depth	Stationary Suction to 3 m of Cover: 20 m Depth
West Erksak High										
*1	15-26	217.0	42.1	47.8	21.8	434.0	63.2	497.2	1,496.3	6,426.8
*2	26-28	16.8	10.2	16.4	8.4	33.6	15.3	48.9	208.3	985.3
3	23-25	10.2	5.8	10.9	5.6	20.4	8.7	29.1	129.3	616.8
*4	26-34	32.1	13.4	19.6	11.7	64.2	20.1	84.3	318.7	1,470.7
5	36-48	2.1	2.0	7.2	1.7	4.2	3.0	7.2	49.0	244.0
6	34-36	2.9	7.2	5.7	2.0	4.8	10.8	16.6	71.9	338.9
7	36-38	1.8	3.9	7.8	10.6	3.6	5.9	9.5	80.4	441.9
8	37-38	1.2	1.6	7.7	2.7	2.4	2.4	4.8	46.9	244.9
9	32-35	5.7	8.7	18.0	6.7	11.4	13.1	24.5	147.4	733.9
10	32-34	0.7	2.4	4.6	2.0	1.4	3.6	5.0	35.4	180.9
11	28-33	1.6	8.6	14.7	6.9	3.2	12.9	16.1	115.4	592.4
12	24-29	8.9	21.0	14.3	15.5	17.8	31.5	49.3	227.8	1,123.3
Erksak Channel										
13	30-35	-	1.1	13.5	7.8	-	1.7	1.7	71.7	407.7
*14	30-33	-	-	7.3	7.2	-	-	-	43.6	261.1
15	28-31	-	-	7.0	5.4	-	-	-	38.0	224.0
16	14-19	-	3.3	8.4	15.6	-	5.0	5.0	83.3	492.8
17	20-33	2.2	4.4	30.9	22.5	4.4	6.6	11.0	195.2	1,095.2
*18	16-23	-	-	20.4	6.2	-	-	-	86.9	485.9
19	15-19	-	-	-	6.5	-	-	-	16.3	113.8
20	14-20	-	-	9.5	10.9	-	-	-	60.5	366.5
Uviluk High										
21	26-30	23.0	2.8	4.8	4.8	46.0	4.2	50.2	156.4	687.4
22	30-32	16.6	5.5	5.5	4.5	33.2	8.3	41.5	138.3	619.8
27	28-30	-	-	0.3	0.6	-	-	-	2.6	16.1
James Shoal Extension										
23	26-28	-	1.1	1.4	0.7	-	1.7	1.7	11.6	59.6
24	27-30	-	1.1	8.4	1.6	-	1.7	1.7	38.4	204.9
25	28-30	-	-	0.2	0.3	-	-	-	1.5	9.0
26	28-30	-	-	0.1	0.3	-	-	-	1.1	7.1

Table 3
Prospective Granular Resource Volume Estimates
(Continued)

Borrow Site	WD m Range	Area 0 m cont km^2	Area 0-1 m cont km^2	Area 1-2 m cont km^2	Area 2-3 m cont km^2	Under 0 m	Volume Estimates Times 10^6 m^3: Hopper Dredge to 2 m Depth Under 0-1 m	Total Hopper	Stationary Suction to 3 m of Cover 5 m Depth	Stationary Suction to 3 m of Cover 20 m Depth
JSE (boreholes only)										
*28	20-22	0.8	-	-	-	1.6	-	1.6	4.0	16.0
*29	8-11	5.3	-	-	-	10.6	-	10.6	26.5	106.0
30	8-11	15.0	-	-	-	30.0	-	30.0	75.0	300.0
Kugmallit Channel										
31	46-51	-	0.6	1.7	0.7	-	0.9	0.9	10.4	55.4
32	50	-	-	-	0.3	-	-	-	0.6	4.4
33	50-55	-	-	-	0.8	-	-	-	1.9	13.1
TOTALS		**363.9**	**146.8**	**294.1**	**192.2**	**727.8**	**220.2**	**948.0**	**3,990.0**	**18,945.0**

Note: "*" indicates borehole control within the prospect area.

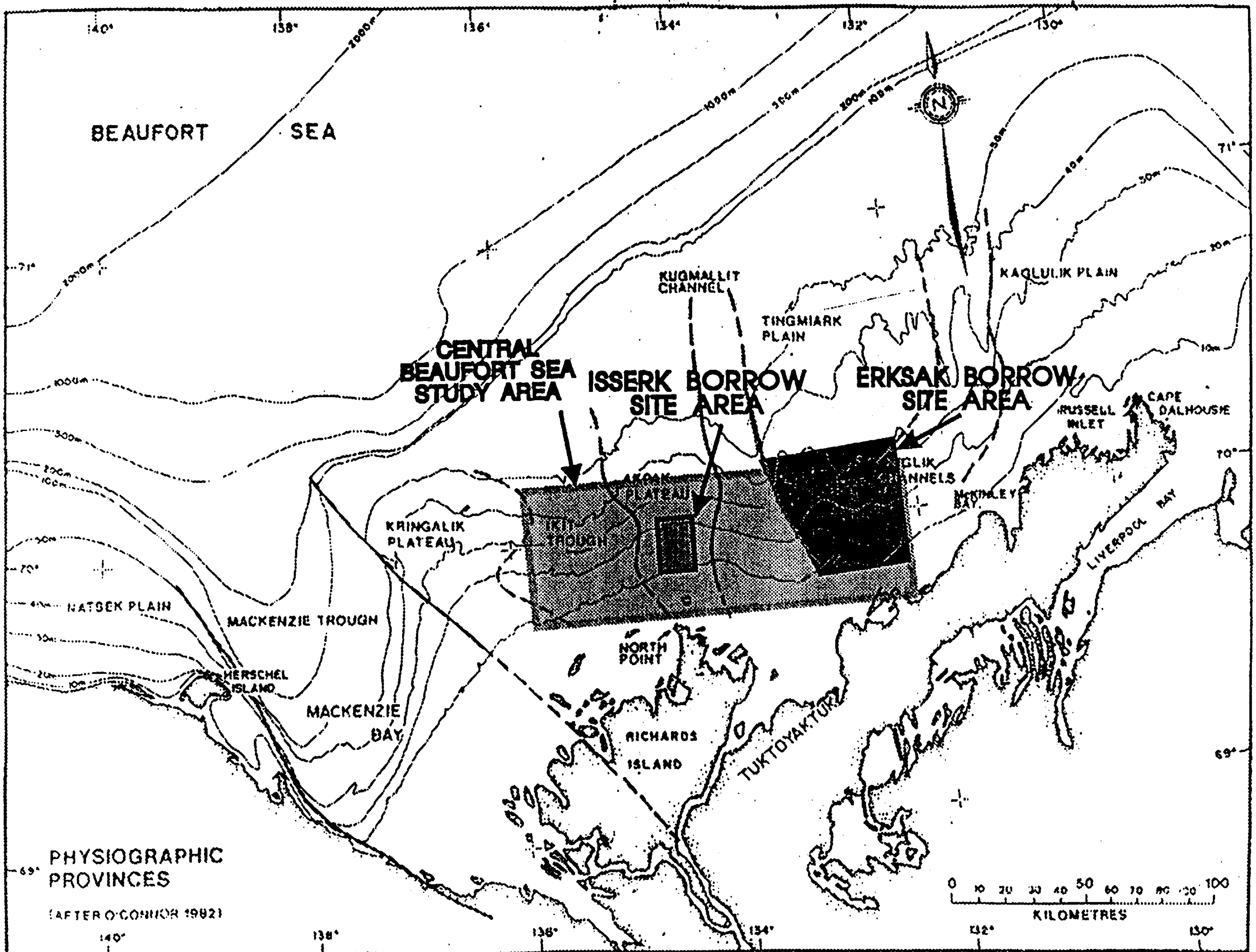
Table 4
Probable Granular Resource Estimates

Site ID	Proven 10^6 m^3	Prospective 10^6 m^3	Probable 10^6 m^3	Comments
West Erksak High				
1	431.3	6,426.9	3,000	Trend toward increasing fines in a northerly direction with considerable fine bedding noted on the seismic records suggesting an increase in the silt and clay component of the sediments. Resource quality is noted to vary significantly with small positional change in borehole tests; thus, estimate 50% to 60% of the prospective resource will be unacceptable though on a localized basis.
2	27	985.3	400	
3	na	616.8	300	
4	36	1,470.7	500	
5	na	244.0	100	
6	na	338.9	100	
7	na	441.9	150	
8	na	244.9	100	
9	na	733.9	200	
10	na	180.9	75	
11	na	592.4	200	
12	na	1,123.3	400	
Erksak Channel				
13	na	407.7	40	Northern reworked-assume low quality factor.
14	0	261.1	25	Northern reworked-assume low quality factor.
15	na	224.0	20	Northern reworked-assume low quality factor.
16	na	492.8	120	Increasing quality southward.
17	na	1,095.2	210	Increasing quality southward.
18	0.4	485.9	240	Good quality proven borehole.
19	na	113.8	70	J.S. Extension.
20	na	366.5	220	J.S. Extension.
Uvliuk High				
21	7	687.4	350	Good proven component; therefore, estimate 50% utility with some localized fine lenses and ignore prospect 27.
22	105	619.8	310	
27	na	16.1	-	
James Shoal Extension				
23	na	59.6	10	Small targets with probable fair to good quality, but sediment cover reduces probability of utilization.
24	na	204.9	40	
25	na	9.0	2	
26	na	7.1	1	

Table 4
Probable Granular Resource Estimates
(Continued)

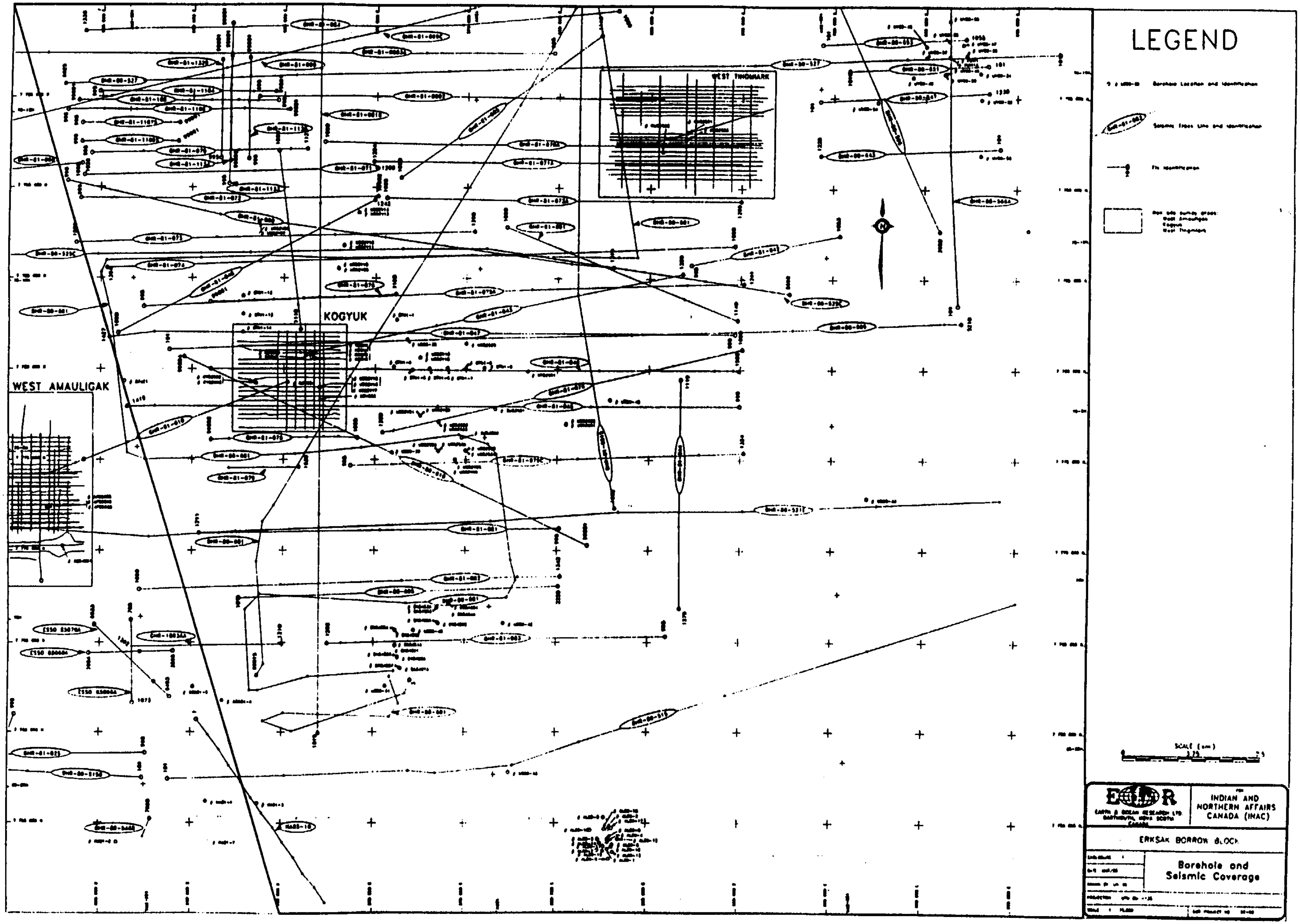
Site ID	Proven 10^6 m^3	Prospective 10^6 m^3	Probable 10^6 m^3	Comments
JSE (boreholes only)				
28	10	16.0	6	Good potential with some fines component and moderately well proven, though significant surficial cover stripping required.
29	100	106.0	75	
30	30	300.0	150	
Kugmallit Channel				
31	na	55.4	0	Small targets of reworked sediment likely containing significant fines and significant surficial cover to strip off.
32	na	4.4	0	
33	na	13.1	0	
TOTAL	**747.7**	**18,945.0**	**7,414.0**	

Note: "na" = no samples available to prove reserve.



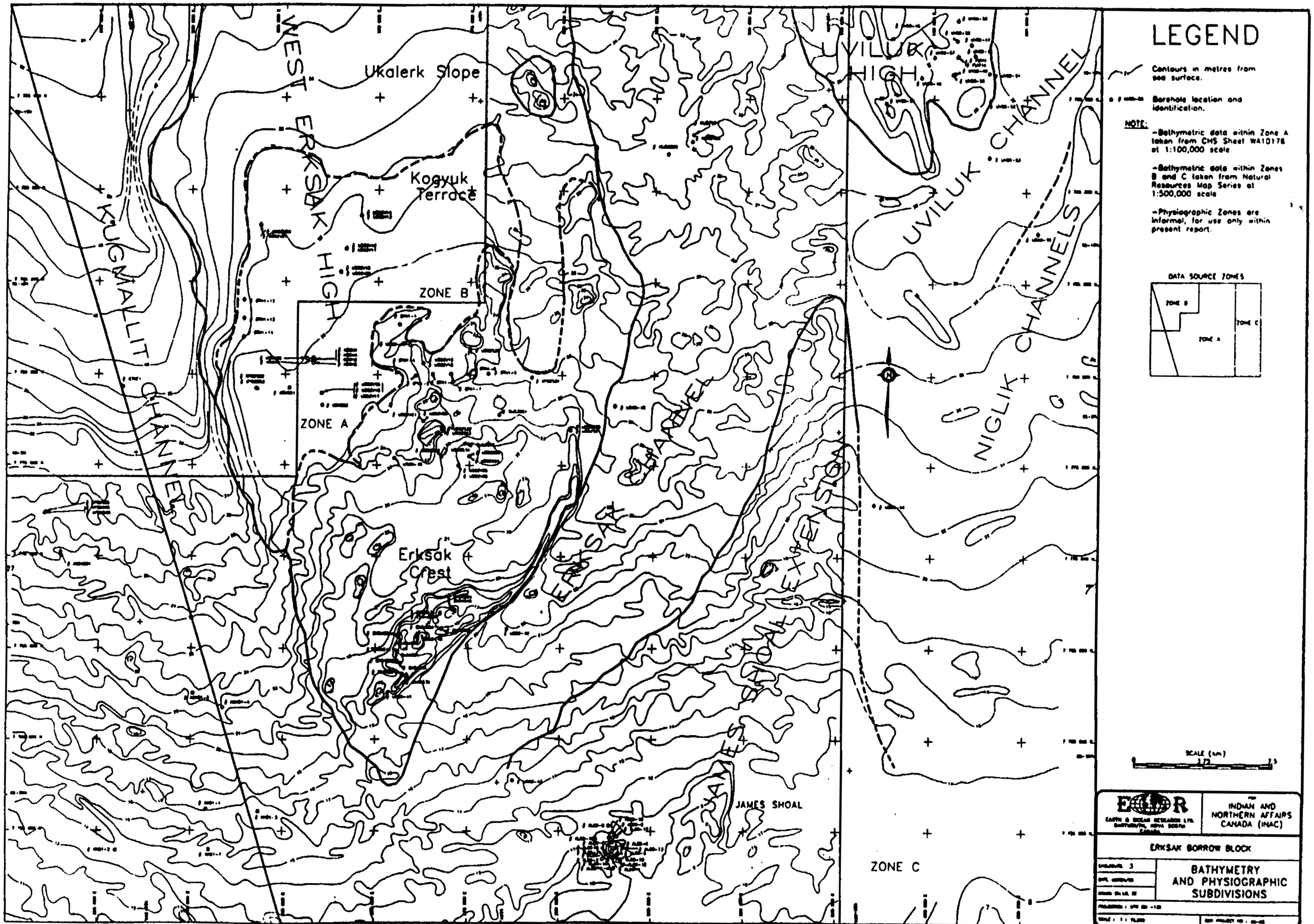
LOCATION DIAGRAM

FIGURE 1



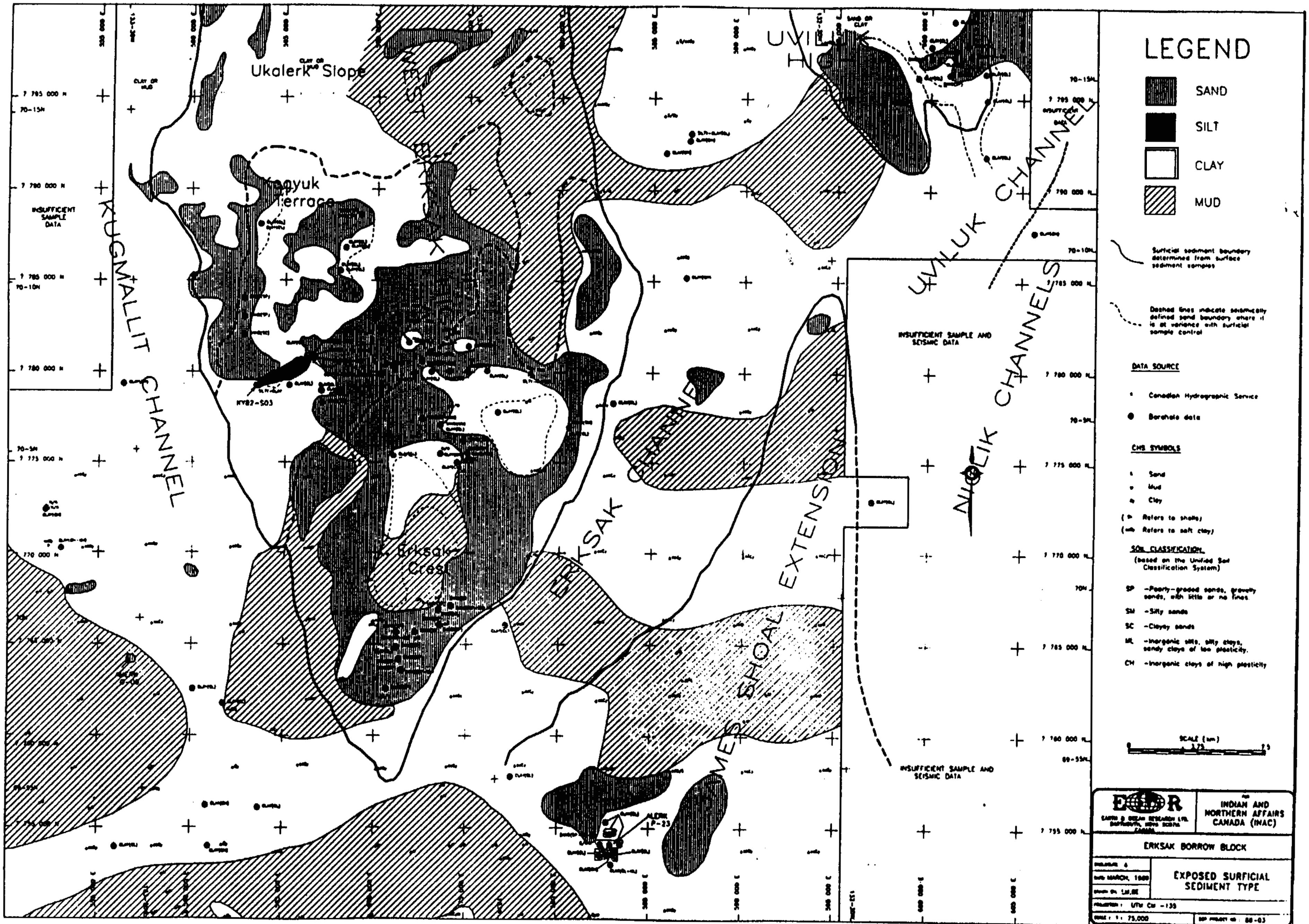
BOREHOLE AND SEISMIC COVERAGE

FIGURE 2



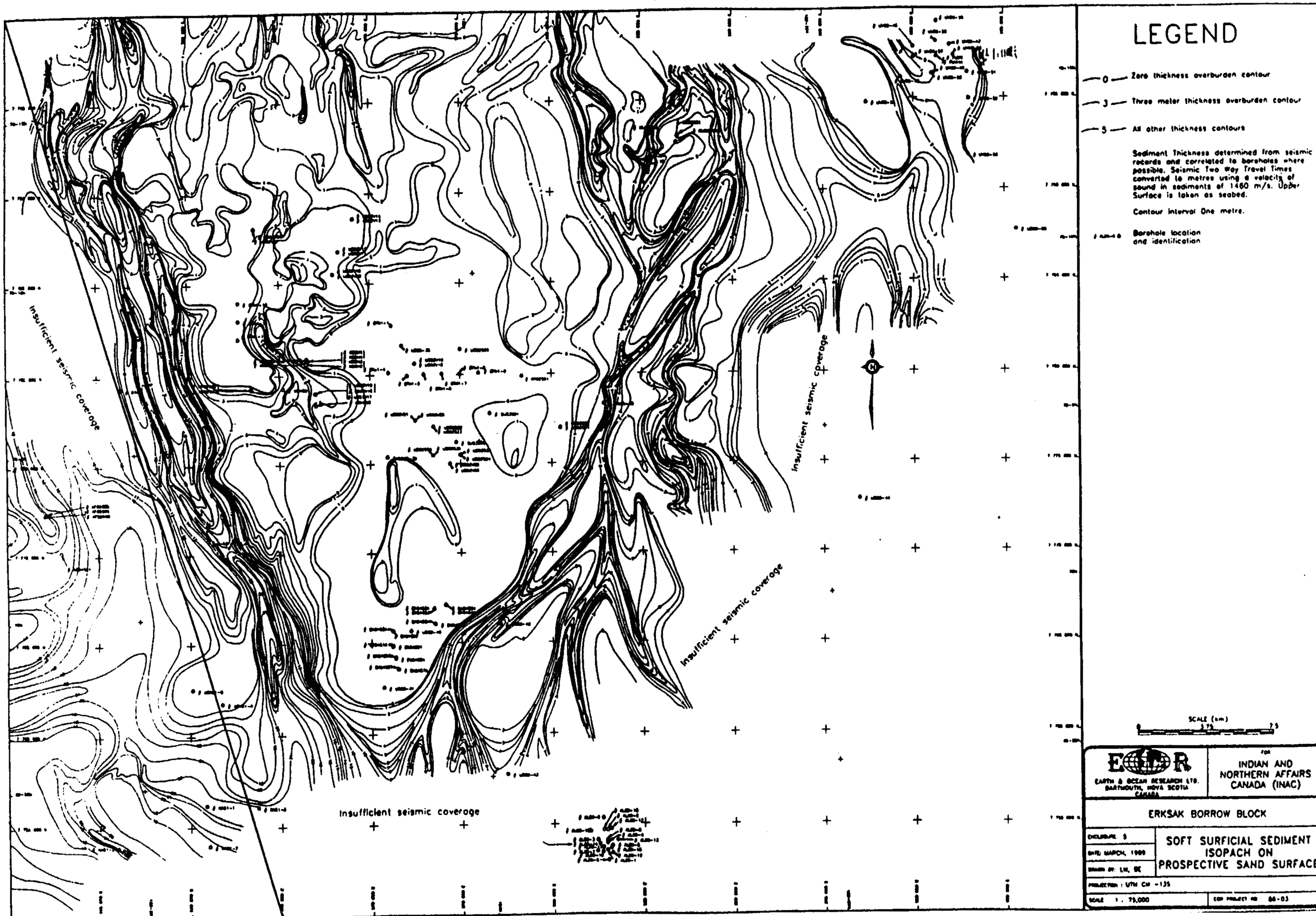
BATHYMETRY AND PHYSIOGRAPHIC SUBDIVISIONS

FIGURE 3



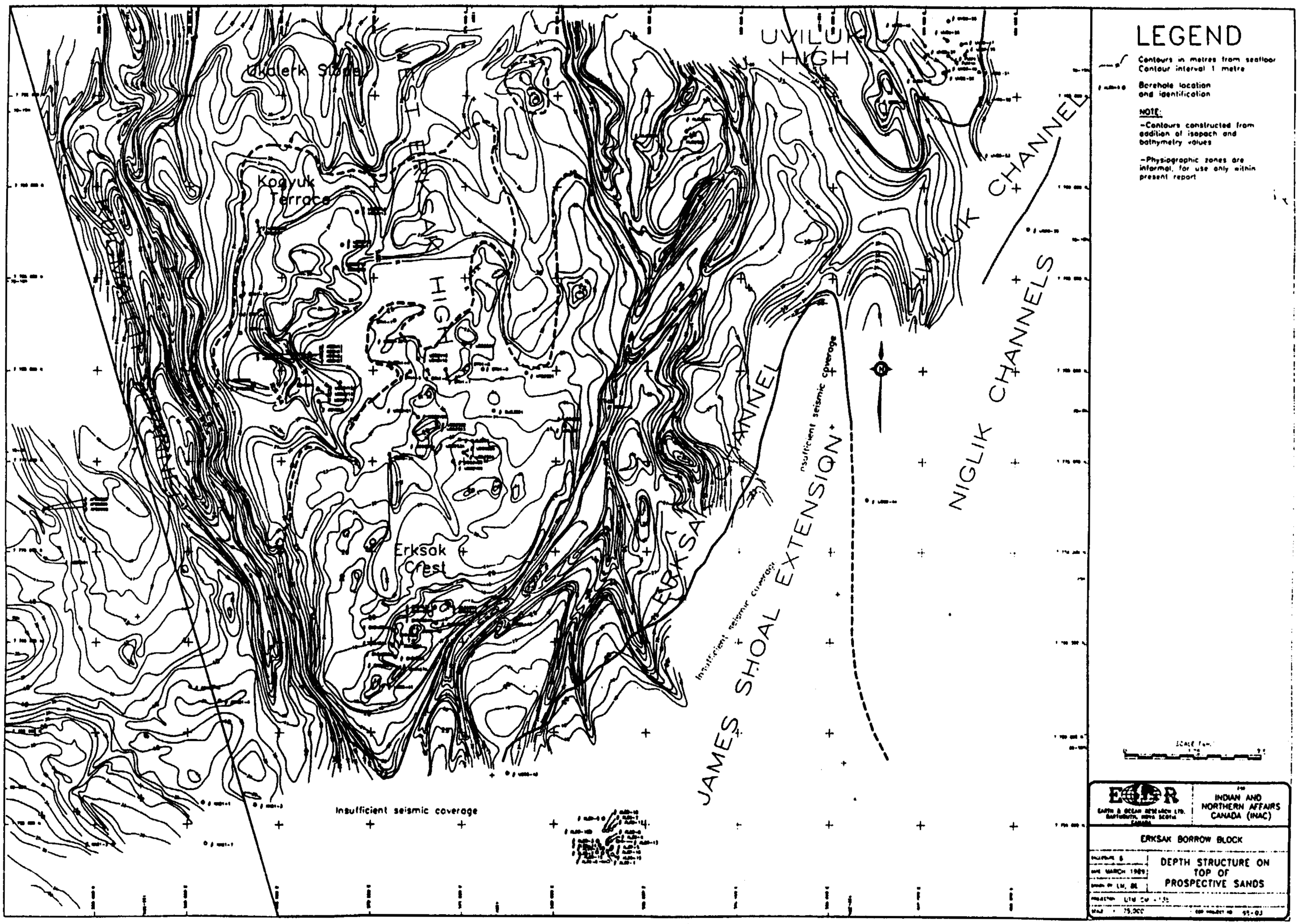
EXPOSED SURFICIAL SEDIMENT TYPE

FIGURE 4



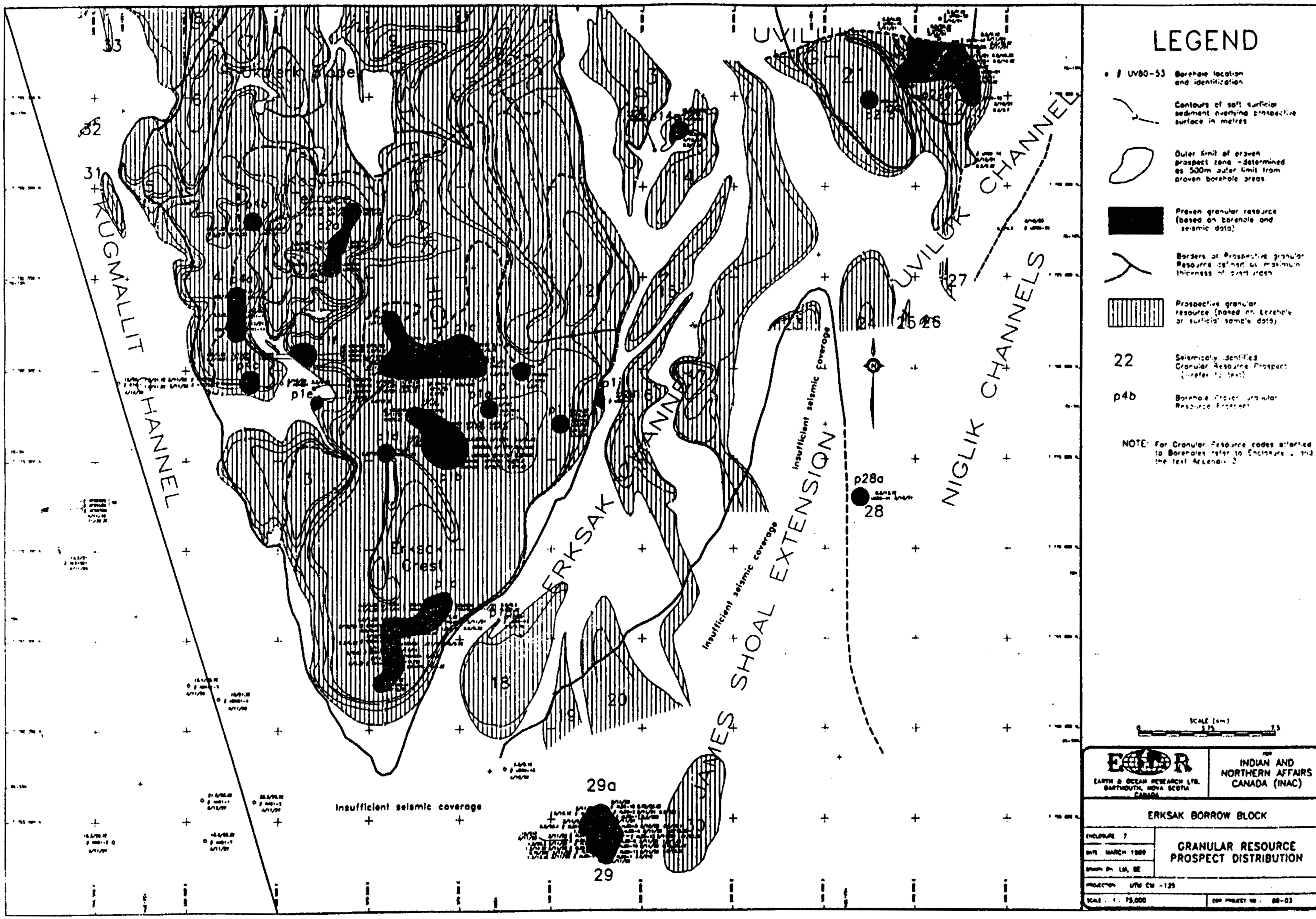
SOFT SURFICIAL SEDIMENT ISOPACH ON PROSPECTIVE SAND SURFACE

FIGURE 5



DEPTH STRUCTURE ON TOP OF PROSPECTIVE SANDS

FIGURE 6



GRANULAR RESOURCE PROSPECT DISTRIBUTION

FIGURE 7

Granular Resources Off The Southwest Coast of Banks Island
(NOGAP Project A4-16)

Presented By Guy R. Fortin
H.R. Seismic Interpretation Services Inc.
Cap-Rouge, Quebec

1.0 Introduction

Despite long sailing distances from present hydrocarbon exploration sites in the central Beaufort Sea, the narrow shelf bordering the southwestern coast of Banks Island has been identified by the Department of Indian and Northern Affairs Canada (INAC) as a prospective area for gravel deposits. Although O'Connor (1983) indicated that more than 50,000,000 m^3 of gravel may exist at suitable depth for dredging between Cape Lambton and Sachs Harbour (Figure 1), the granular resources in this area remain largely unexplored. Between 1981 and 1983, three separate geophysical programs have been carried out by the industry to investigate the surficial geology for gravel deposits off the island coast. The results of two site specific surveys conducted in 1981 and 1982 at the mouth of the Masik and Rufus rivers have been reported to Dome Petroleum by Fortin (1982 and 1984; Figure 1). A detailed evaluation of the regional survey completed in 1983 was prepared by Fortin (1987) on behalf of INAC (A4 NOGAP project; Sub-Project A4-16). The regional survey includes six lines totalling 130 km of seismic data (echo sounder, side scan sonar, sub-bottom profiler, boomer and air gun systems) recorded in water depths oscillating between 10 and 25 m. The present paper summarizes the findings of the 1983 regional survey. This information was presented with more details in Fortin (1987) who constructed three synoptic plates showing both on-shore and off-shore geology (Plates I, II and III; Figure 1).

2.0 On-Shore Geology (Vincent, 1983)

The surficial geology of the coast is dominated by morainal deposits that include three distinct glacial till sheets; the Bernard, the Sachs and the Carpenter tills (Table 1 and Figure 2). The Bernard Till (Unit 2; Figure 2) covers extensive areas of the western region of Banks Island and is present north of Sachs Harbour. This deposit is relatively thin (1-10 m) and comprises a fine-grained matrix. The distribution of the Sachs Till (Unit 12; Figure 2) has been particularly well established in the Sachs Harbour and Masik River areas. The Sachs Till is thin (1-2 m) and includes a sandy matrix with a high fraction of sediments coarser than 2 mm. The Carpenter Till (Unit 15; Figure 2) extends along the coast between Masik River to the south and Middle Lake to the north. The Carpenter Till is characterized by a sandy and rocky matrix, as well as a significant proportion of gravel and rock fragments. Of particular interest is the "young" morphology of the Carpenter Till which consists of crests of till and ice contact deposits oriented parallel to the coast and separated by kettles. The main till properties are summarized in Table 1. In the near shore area, deposits of borrow materials may originate from erosion and reworking of these three till units, as well as from undifferentiated Quaternary deposits (Unit 1; Figure 2) that include stratified sand and gravel deposited by glacial meltwater at the mouth of the Masik River.

Table 1
Till Properties

Till Units	N	Grain Size (%)				Characteristics
		>2 mm	Sand	Silt	Clay	
Bernard Till (Unit 2, Figure 2)	34	28.7	45.0	33.0	22.0	Blackish colour and fine matrix. Fraction >2 mm: high proportion of sedimen-tary rocks (carbonates, sandstones and chert), small proportion of igneous rocks (diabase and gabbros).
Sachs Till (Unit 12, Figure 2)	3	50.7	61.4	21.8	16.8	Light colour, sandy matrix and high fraction >2 mm. Fraction >2 mm: mainly sedimentary rocks (carbo-nates and sandstones), higher proportion of gabbros than other tills.
Carpenter Till (Unit 15, Figure 2)	1	38.6	46.5	32.2	21.3	Sandy and rocky matrix. Fraction >2 mm: high proportion of gravel and diabase rock fragments. Granitic rocks within the till.

Note: N - Number of samples.

3.0 Discussion on Off-Shore Borrow Prospects

The procedure used to predict the occurrence of aggregate deposits near the seabed is mainly based on qualitative interpretations of seismic data as only six sediment samples were taken along the survey lines. For this reason, the geological inferences propose herein may not be exact at specific sites since only a detailed seabed sampling program can confirm the presence and extent of borrow deposits.

Given the limitations inherent to the dredging techniques used at the present time and in the foreseeable future, eleven target areas have been identified as borrow prospects (Table 2 and Figure 2). Several of the promising sites (high or fair priority) appear to coincide with off-shore extensions of the Sachs Till or Bernard Till and their associated morainic system (Sites B, C, E, J and K). These relatively old deposits may have been reworked at several times in the past which would have resulted in pockets of well sorted materials lying on a flat seafloor (Figure 3). Another high priority site (Site A) may include glaciofluvial sand and gravel deposited at the mouth of the Masik River. Although gravel resources are likely associated with the off-shore extension of the Carpenter Till, this type of deposits (Site D) has a low potential as a result of its high seabed relief, its young appearance (little reworking) and the presence of numerous erratics (Figure 4).

Recommendations for follow-up studies (Table 2) are made on a site specific basis in order to improve our understanding of the geological setting of each individual borrow prospect and to determine the extent and quality of the granular deposits. In addition, the portion of the shelf between Middle Lake and Mary Sachs Creek is designated for future regional investigations.

4.0 Conclusions

Based on the available acoustical data and a very limited amount of bottom samples, one may conclude that the potential for gravel deposits is important between the mouth of the Masik River and Duck Hawk Bluff (Figure 2). However, the very uneven seafloor relief in certain areas (Carpenter Till) and the complexity of stratigraphic conditions encountered in several places present challenging environmental obstacles to the safe and efficient dredging of these granular resources. In addition, development of these patchy deposits will require accurate horizontal control systems aboard the dredges. The potential for gravel in the surveyed area off Cape Kellett Spit appears to be low because of both the presence of a fine- to medium-grained (silt and fine sand) surficial layer covering this area and the absence of source deposits (till units) for very coarse materials.

With respect to the complex geology, great diversity of source deposits, poor seismic coverage and near absence of ground-truth information, there is an obvious need for both additional high-resolution seismic reflection and refraction data. These surveys will serve to position bottom sediment samples and shallow boreholes at critical locations in order to determine the quality and exact thickness of the granular deposits.

Table 2 - Summary Table of Off-Shore Borrow Prospects

Site	Priority	Prognostic	Constraints to Future Development	Recommended Future Studies[1]				
				Sample	Geo	Mosaic	Photo	Drill
"A"	High	Large volume of well sorted materials (fluvioglacial deposits?). Re-worked sand with some gravel.	Shallow gas might cause difficulties during drilling of deep holes.	(1)	(2)	—	—	(3)
"B"	High	Fair volume of patchy materials (sand and gravel). Till (Sachs?) outcrops. Erratics.	Number of erratics (cobbles and boulders) near seabed may increase toward the Sachs Till outcrops.	(1)	(2)	(3)	(4)	(5)
"C"	Fair	Small volume of thin patches of re-worked materials (sand and gravel) atop a till (Sachs?) surface. Frequent erratics.	Frequent outcrops of an old till surface (poor sorting, high compaction, possibly ice-bearing). Numerous erratics visible on sonograph. Proximity of the coast.	(1)	(2)	(3)	(4)	(5)
"D"	Low	Re-worked materials originating from a young till sheet (Carpenter Till?). Westward fining facies change.	Irregular sea floor. Erratics may be common. Till outcrop (poor sorting, high compaction possibly ice-bearing). Proximity to the coast.	(1)	(2)	(3)	(4)	(5)
"E"	Fair	Patches of re-worked sand with some fine gravel. Frequent out-crops of a fine-grained till (Sachs or Bernard Till?).	Frequent outcrops of a till surface (poor sorting, high compaction, possibly ice-bearing). Patchy nature of good granular materials. Possible presence of erratics. Proximity to the coast.	(1)	(2)	(3)	—	(4)
"G"	Low	Thin veneer of re-worked sand with some gravel. Fining facies change away from the source deposit (fine-grained till?).	Occurrence of till outcrops that may include fine-grained units, highly compacted and ice-bearing sediments.	(1)	(2)	(3)	—	(4)
"H"	Low	Thin veneer of re-worked sand with some gravel originating from an old till unit (Sachs or Bernard Till?).	Occurrence of till outcrops that may include fine-grained units, highly compacted soils and ice-bearing sediments. Marginal volume of borrow.	(1)	(2)	(3)	—	(4)
"I"	Low	Lag deposit? Submerged coastal feature?	Geologic origin not well established. Marginal potential?	(1)	(2)	—	—	(3)
"J"	Fair	Thin veneer of re-worked sand with some gravel originating from an old till unit (Sachs or Bernard Till?).	Frequent outcrops of a fine-grained till (Sachs or Bernard Till?) that may include a variety of lithologies, highly compacted soils and ice-bearing sediments.	(1)	(2)	(3)	—	(4)
"K"	High	Large volume of re-worked sand and gravel originating from a frontal moraine (Sachs Till?).	No serious constraints.	(1)	(2)	—	—	(3)

<u>Notes</u>: [1] The recommended future studies should not be conducted simultaneously, but in the order shown. One should proceed with the next step only if the results of the previous step(s) dictate additional works.

Sample: Seabed sampling (grab samplers and corers).
Geo: Detailed geophysical program including precision bathymetry, side scan sonar, sub-bottom profiler, uniboom and deep-tow refraction data.
Mosaic: Preparation of a sea floor mosaic from side scanning imagery.
Photo: Seabed photographs and/or video, diving.
Drill: Shallow geotechnical drilling.

5.0 References

Fortin, G.R. (1982). Marine Bottom and Sub-Bottom Survey, Banks Island Borrow Site, Beaufort Sea. Report submitted to Dome Petroleum Ltd. by Geoterrex Ltd., Project No. 93-15.

____________ (1984). Marine Bottom and Sub-Bottom Survey, Banks Island Gravel Search. Report submitted to Dome Petroleum Ltd. by Geoterrex Ltd., Project No. 93-28.

____________ (1987). Interpretation and Synthesis of High Resolution Reflection Seismic Data from Banks Island Borrow Area. Report submitted to Department of Indian Affairs and Northern Development by H.R. Seismic Interpretation Services Inc., Project NOGAP A4; Sub-Project A4-16.

O'Connor, M.J. (1983). Regional Inventory of Off-Shore Gravel Prospects, Canadian Beaufort Sea. Report submitted to Department of Indian Affairs and Northern Development by M.J. O'Connor & Associates.

Vincent, J.-S. (1983). La Géologie Quaternaire et la Géomorphologie de l'Ile Banks, Arctique Canadien. Commission Géologique du Canada, Mémoire 405, 118 pp.

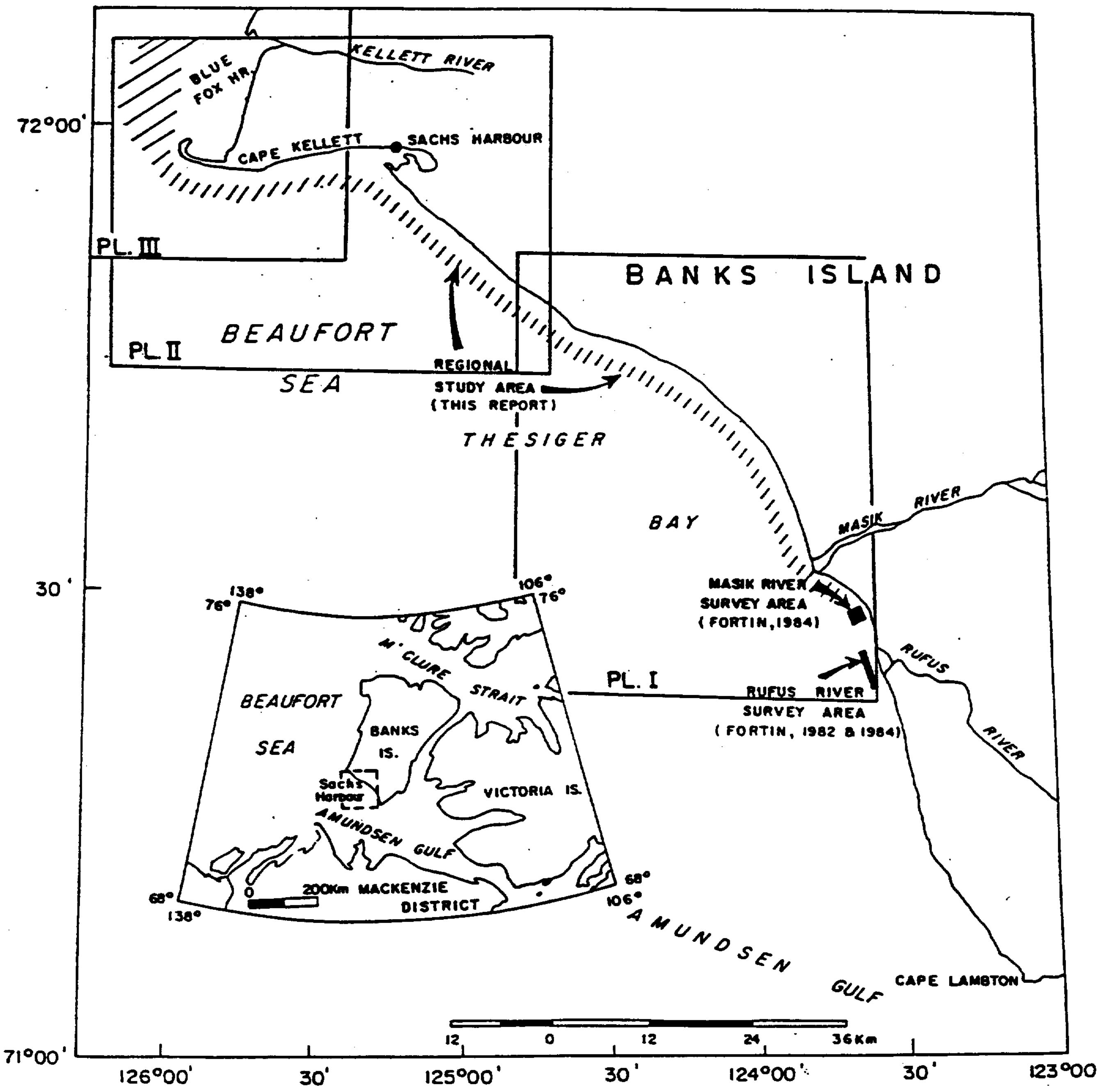


FIG. 1 LOCATION MAP

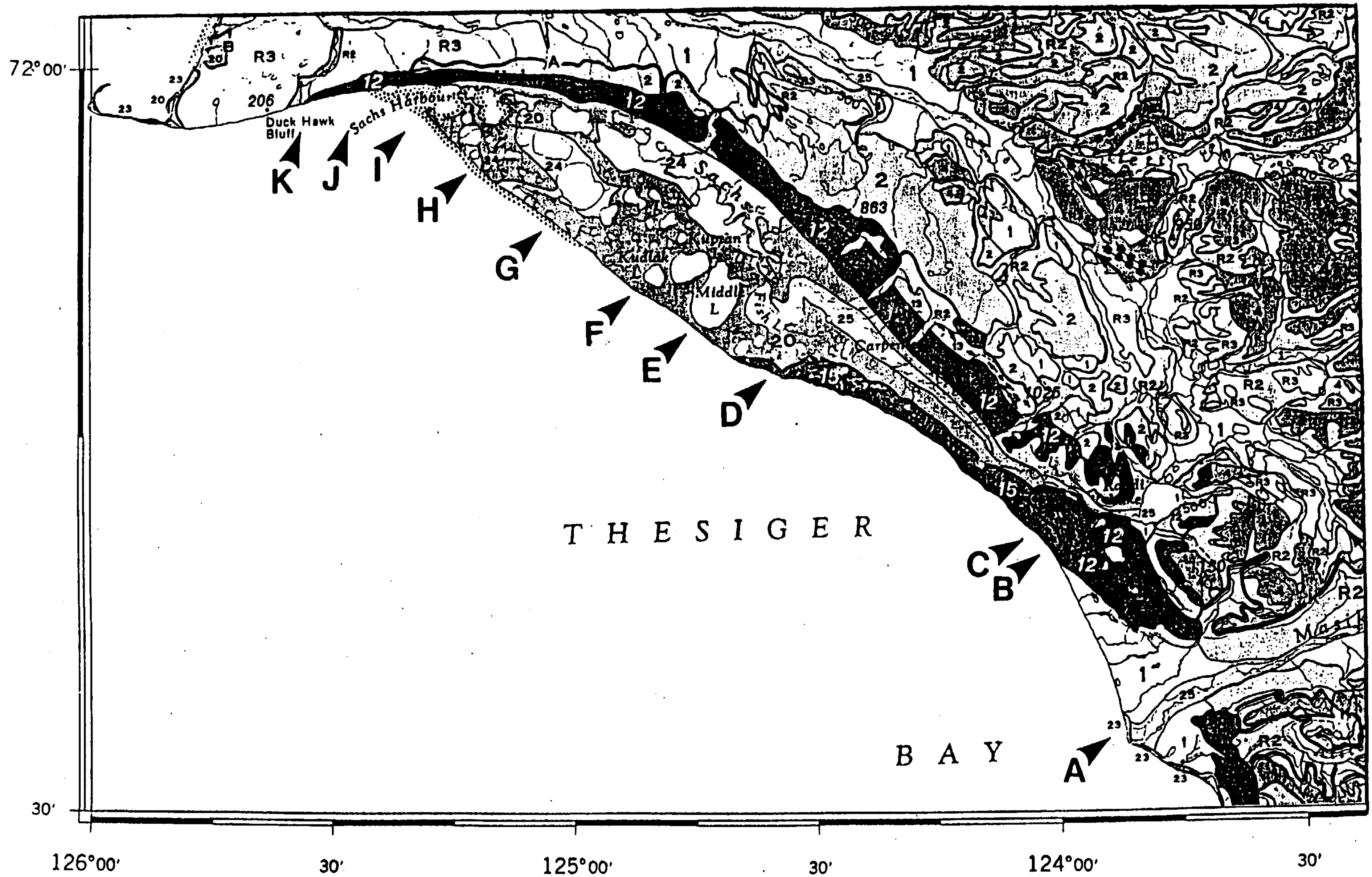
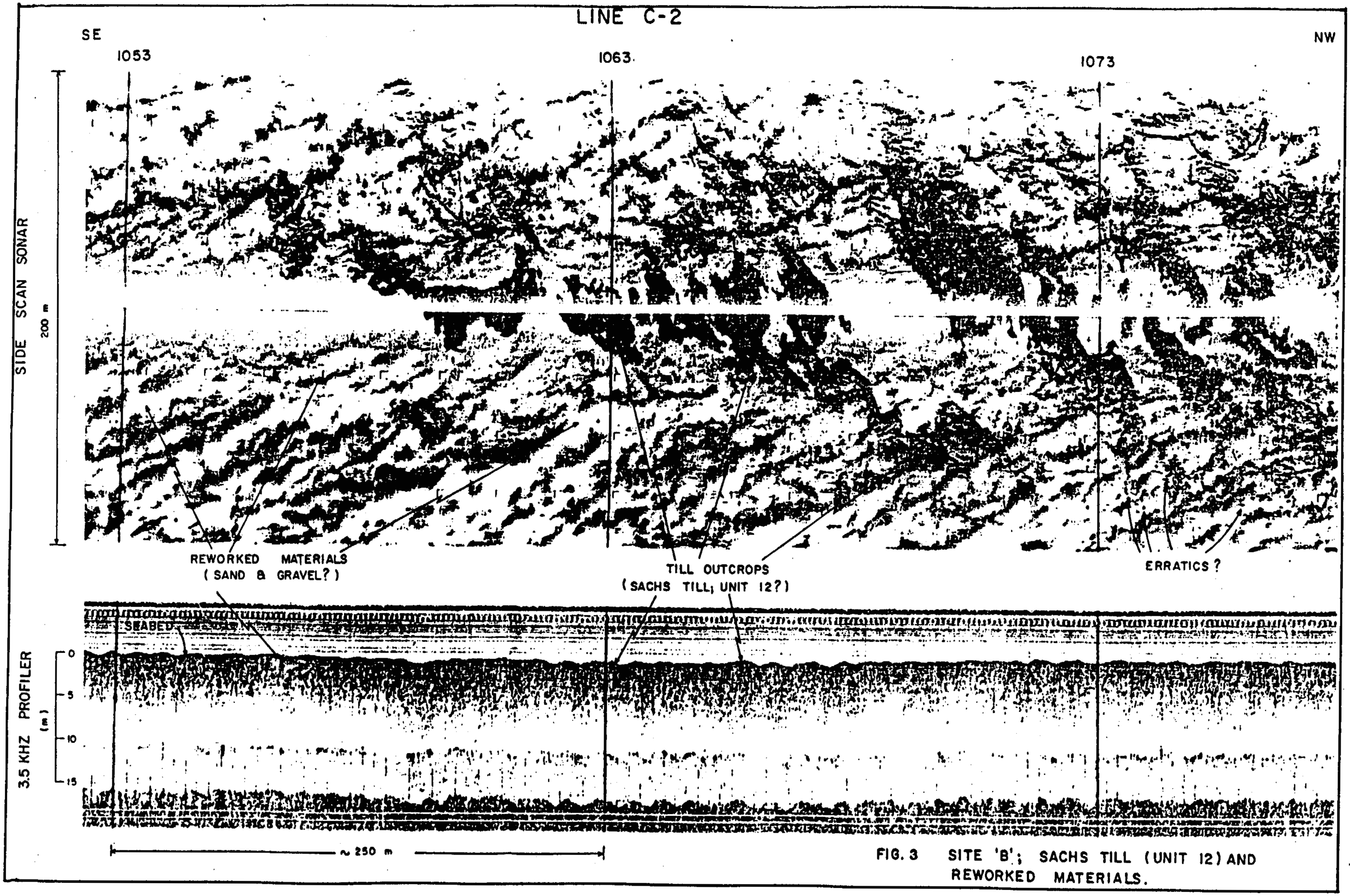
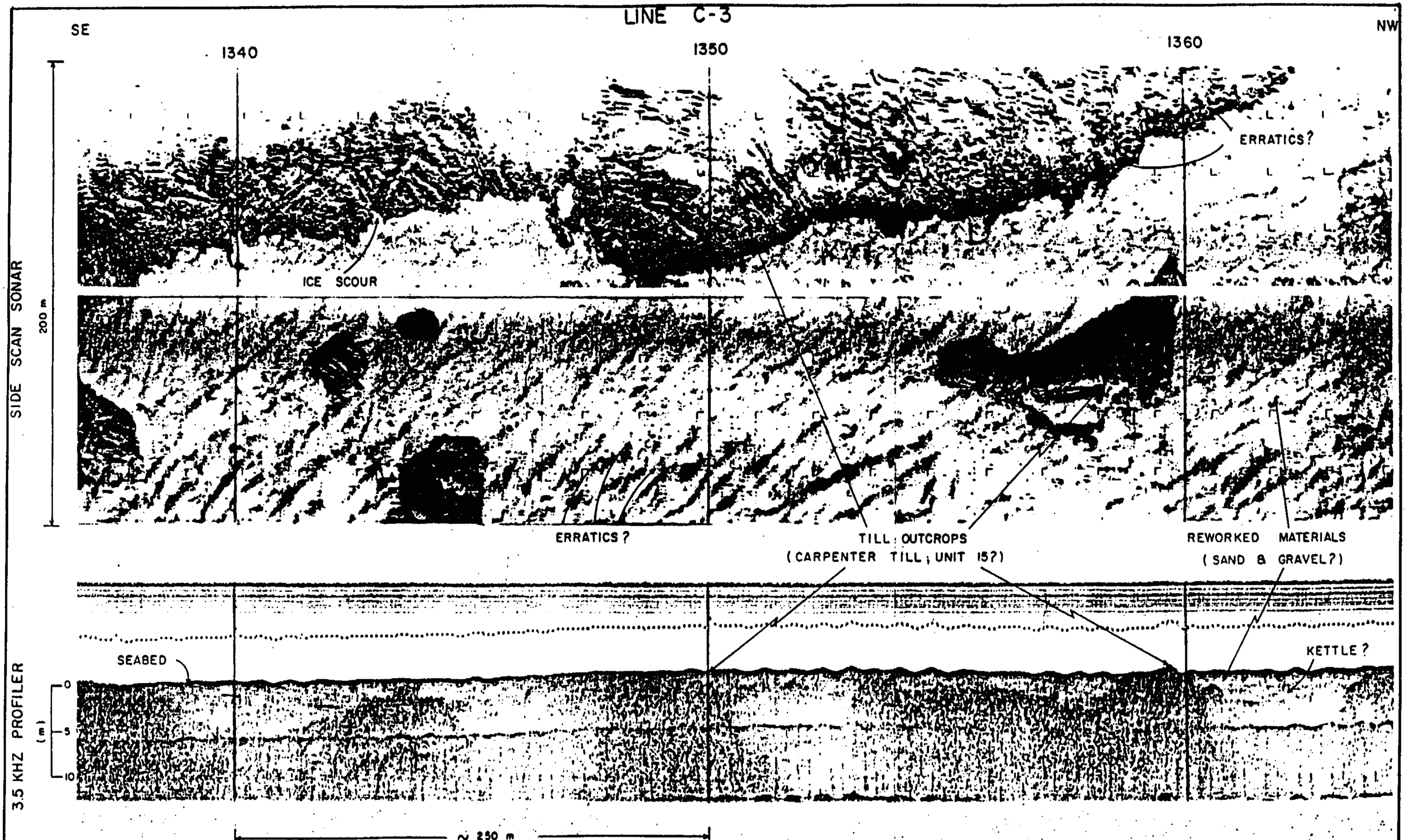


Figure 2. Onshore geology (Vincent, 1983) and approximate location of offshore borrow prospects (Fortin, 1987).



SITE 'B'; SACHS TILL (UNIT 12) AND REWORKED MATERIALS

FIGURE 3



CARPENTER TILL (UNIT 15) AND REWORKED MATERIALS

FIGURE 4

PART 2

REPORTS ON NOGAP R & D STUDIES

Northern Granular Resources
Mapping Information System

Presented By John Peters
Earth & Ocean Research Limited
Dartmouth, Nova Scotia

1.0 Introduction

Indian and Northern Affairs Canada (INAC) has, over the past four years, compiled an extensive inventory of information pertaining to granular resources in the Arctic.

Funded under the NOGAP program, the project has evolved from a digital inventory of high resolution marine seismic track line data, to digital renditions of interpreted geological maps, borehole locations, borrow sites and the encapsulation of all of this data into a user-friendly data management and desktop mapping system called "**inFOcus**".

This paper describes the development of the inventory, its contents and the way that the data can be used to assess and plan activities through the simple and powerful interface provided by the **inFOcus** software.

2.0 Project History

The Arctic Granular Resources Inventory started in 1988 with the compilation and conversion into digital form of industry and government regional and site survey track lines.. A large body of hard copy shot point maps and some digital shot point data were digitized and converted into the format for INAC's mapping system.

It was clear that effective use of the inventory would require its organization within a geographic information system (GIS). However, it was recognized that GIS is not an appropriate technology for inventory applications, especially considering the high capital, training and maintenance costs that are associated with this technology. In 1990, EOR proposed the assembly of the inventory within **inFOcus**, a simple, inexpensive data management and mapping system well suited to interrogating and visually overlaying diverse geo-referenced data sets (see Figure 1).

All of the track data compiled to date, the Beaufort borehole database and a body of interpreted geological maps were imported into **inFOcus**.

The inventory was expanded in 1991 to include a graphical database of on-land borrow sites digitized from aerial photographs. Further work is currently in progress to update the seismic tracks, build on the borrow sites inventory and to provide linkages to the ESEBASE borehole management system that contains a comprehensive borehole geotechnical database.

3.0 Inventory

Below is a summary of the inventory as it has so far evolved.

3.1 High Resolution Marine Seismic Track Lines

Over 1,500 track lines spanning 29,000 line-km have been digitized and imported into **inFOcus**. These comprise:

- All government lines surveyed up to and including 1986 - 355 lines covering 14,000 line-km..

- All regional lines shot by Esso, Gulf and Dome to the end of 1986 - 581 lines covering 12,000 line-km.

- All site survey lines shot by Gulf and Dome in the Isserk and Erksak borrow blocks. This consists of 9 out of a total of 19 surveys conducted by Gulf in the region up to 1986 and 12 out of a total of 40 conducted by Dome. None of the site surveys conducted by Esso have been digitized.

This is not a navigation database. The intent is to be able to assess coverage, especially in the context of other information such as borehole locations and the distribution of geological units, bathymetry, lease boundaries etc. In most cases, a sufficient number of shot points have been digitized to define way points and to correlate shot point ranges to a particular geographic area.

It is now realized that digitized track lines within site surveys is overkill and that the outline of the survey area would be just as useful. The study catalogue compiled by McElhanney in 1988 provides co-ordinates of the study areas. This database has been imported into **inFOcus** and outlines of survey areas can be plotted for all studies completed up to the end of 1986.

3.2 Boreholes, Grabs and Cores

All borehole sites compiled up to 1988, updated to 1990 and supplemented with vibracore and grab sites, are accessible within the **inFOcus** system (see Figure 2). Summary attributes, such as hole id, owner, drill depth, etc., are contained within each record and can be accessed directly from the map of hole locations.

It is planned to import the full geotechnical database compiled by EBA so that selections of holes for map display can be based on a broad range of geotechnical search criteria.

3.3 Geological Maps

Geological maps associated with detailed studies of granular resources in the Isserk and Erksak borrow blocks have been imported into the **inFOcus** system. These include data control, bathymetry, isopaches of geological units and interpreted resource potential maps. These can be overlaid with one another or with seismic and borehole database information for further analysis (see Figure 3).

In 1991, geological maps associated with additional studies in the Herschel and Banks Island regions were digitized and imported into the system.

3.4 Borrow Sites

A major part of the 1991 inventory project was the construction of a graphical database of on-land borrow sites (see Figure 4). Source data for most of the entries were aerial photographs at approximately 1:36000 scale. Outlined deposits were digitized and linked to database records containing attribute information such as site id, resource type, geologic origin, etc. Site plan inventories have been compiled into **inFOcus** for the following areas:

- Mackenzie Valley.
- Alaska Highway corridor.
- Dempster Highway corridor
- South Slave area.
- Inuvialuit Settlement area.
- Individual communities such as Fort Good Hope and Fort McPherson.

4.0 Data Management and Retrieval

The Northern Granular Resources Mapping Information System provides a comprehensive inventory of deposit, borehole, seismic and geological information. These data can be displayed as maps and printed or plotted in various projections and at any scale.

The data are organized into "applications" focusing, for example, on seismic data or borrow sites or a particular geographic region. The data management sub-system provides the full capabilities of a relational database management system within a "point and click" non-technical user interface. The user is presented with menus of "English" descriptions (see Figure 5) of data sets or maps instead of file names and can construct, using a mouse:

- Complex queries without a knowledge of command syntax.
- Reports based on hard-wired or custom formats.
- Maps consisting of multiple overlays such as bathymetry, isopaches, borehole locations and seismic coverage.

Figures 5, 6 and 7 which follow this text show the data management interface and some example maps printed on a laser printer at low resolution. High quality figures can be produced on high resolution laser printers and plotters.

5.0 Current Activities

Planning is in progress to expand and refine the inventory. The following aspects are being considered:

- Update of the high resolution marine seismic coverage.
- Expansion of the on-land borrow site inventory.
- Import of the Yukon Shelf regional geology study.
- Refinement of database structures and cross-linkages.
- Enhancement of the applications through improved data organization, customized queries and reports.
- Development of procedures to report and update inventory statistics.

The aim in the present project is to provide a fully operational planning tool for granular resource management in the north. In support of this, several new initiatives also should be considered for future work.

6.0 Future Initiatives

Presently, the base map for the inventory data is derived from the 1:2,000,000 scale CIA world data bank. For many applications, detailed cultural and topographic information will be vital. A first step would be to import the 1:250,000 NTS series digital base maps for all or specific regions of the north. All of the maps are available for import into **inFOcus**. An example of these maps is provided for the area covering western Yukon.

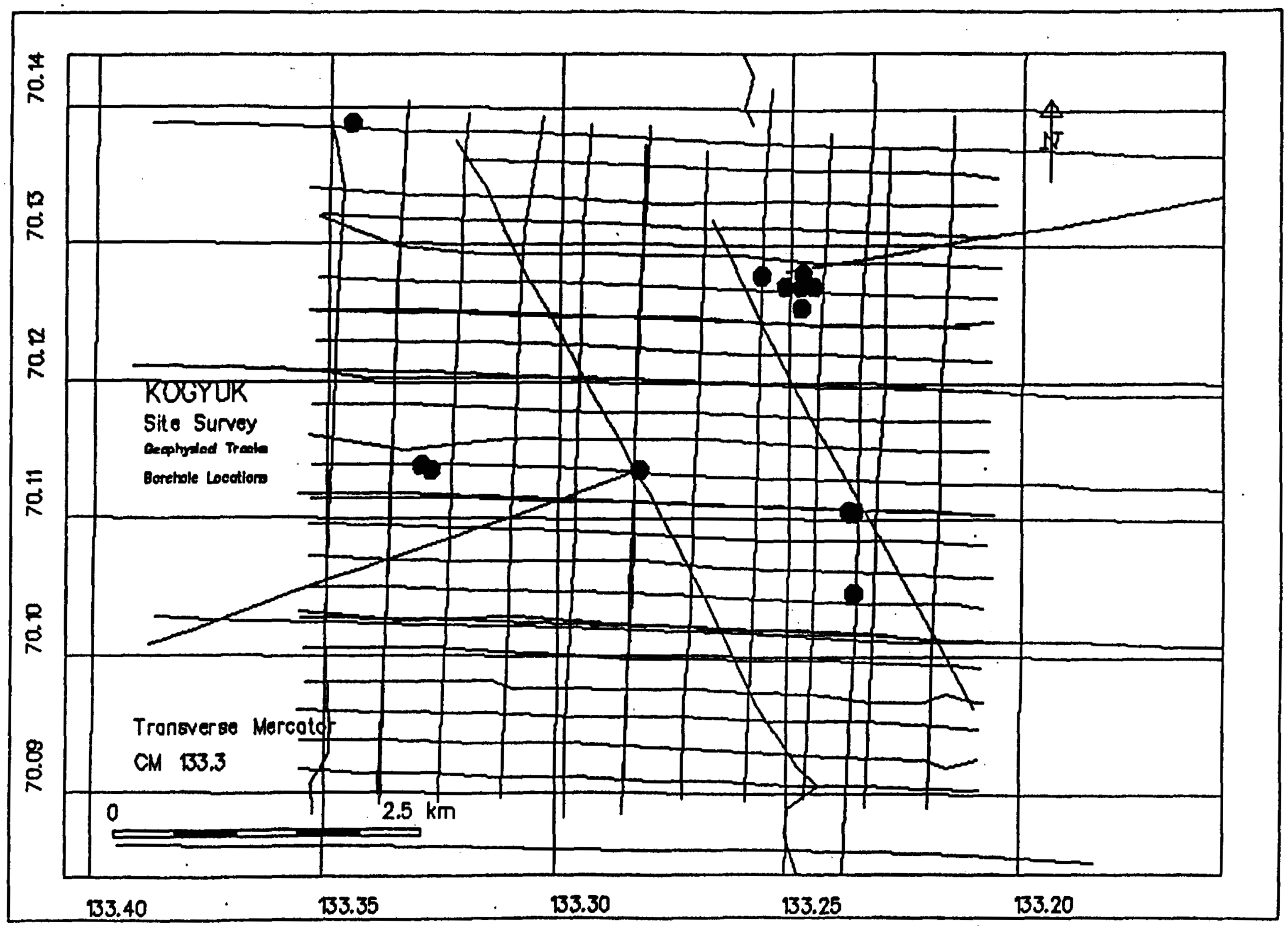
The off-shore equivalent is regional bathymetry for the Beaufort Sea. Sub-sets of the region are available in digital form from Canadian Hydrographic Service. However, a uniform scale coverage at 1:1,000,000, for example, would be of major benefit for many applications.

Any resource development and management plan must consider information related to jurisdiction, land ownership and control, environmental impact and development infrastructure. The Northern Granular Resource Mapping Information System lends itself to integration with these types of data. **inFOcus** applications have developed elsewhere that integrate geological, fishery, environmental, cultural and land use data that are used together to target resource conflicts and environmental sensitivities. Examples are:

- IRMIS (Integrated Resource Management Information System) for off-shore Prince Edward Island.
- IRMIS for coastal zone Nova Scotia.
- NATLUS - the national protected lands database.

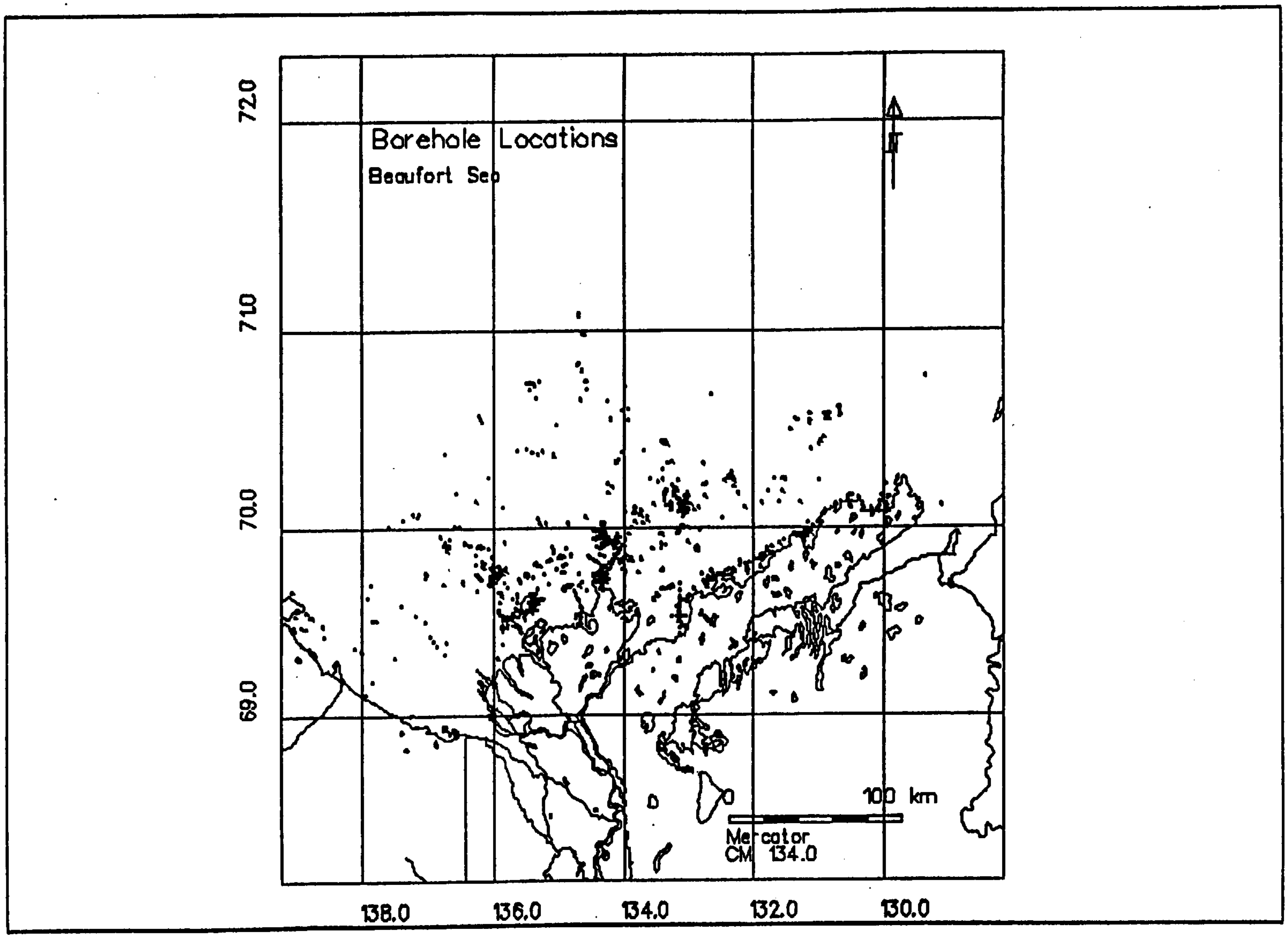
New and existing land use and environmental databases should be imported into the system and routine procedures developed to address common planning issues in a timely fashion. One of the compelling advantages of the **inFOcus** approach is its low cost and high user accessability. Data can be delivered to all users easily.

Effective planning and advocacy for resource development is dependant on the ability for all interested groups to share and comprehend the same data. One example is the promotion of the NATLUS application by the mining industry. On the one hand, it provides a tool for the industry to assess land access restrictions. On the other, it will provide native peoples and jurisdictions a clear picture of their rights and responsibilities. All parties will be able to argue their agendas based on the same information. This approach will become critical for all aspects of resource development in the north.



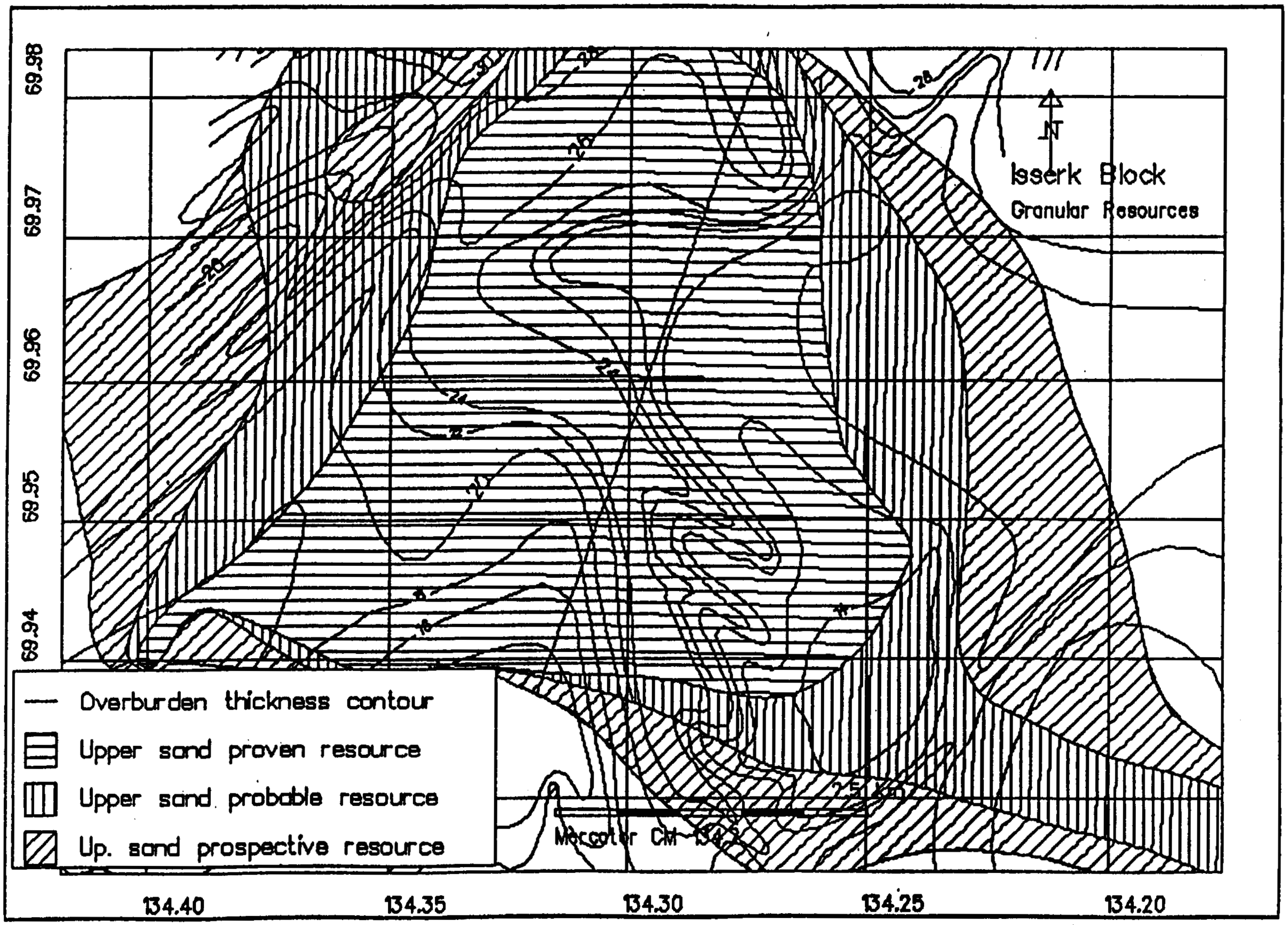
The Kogyuk Site Survey is one of several detailed geophysical and geotechnical site survey programs accessible within the existing data base.

FIGURE 1



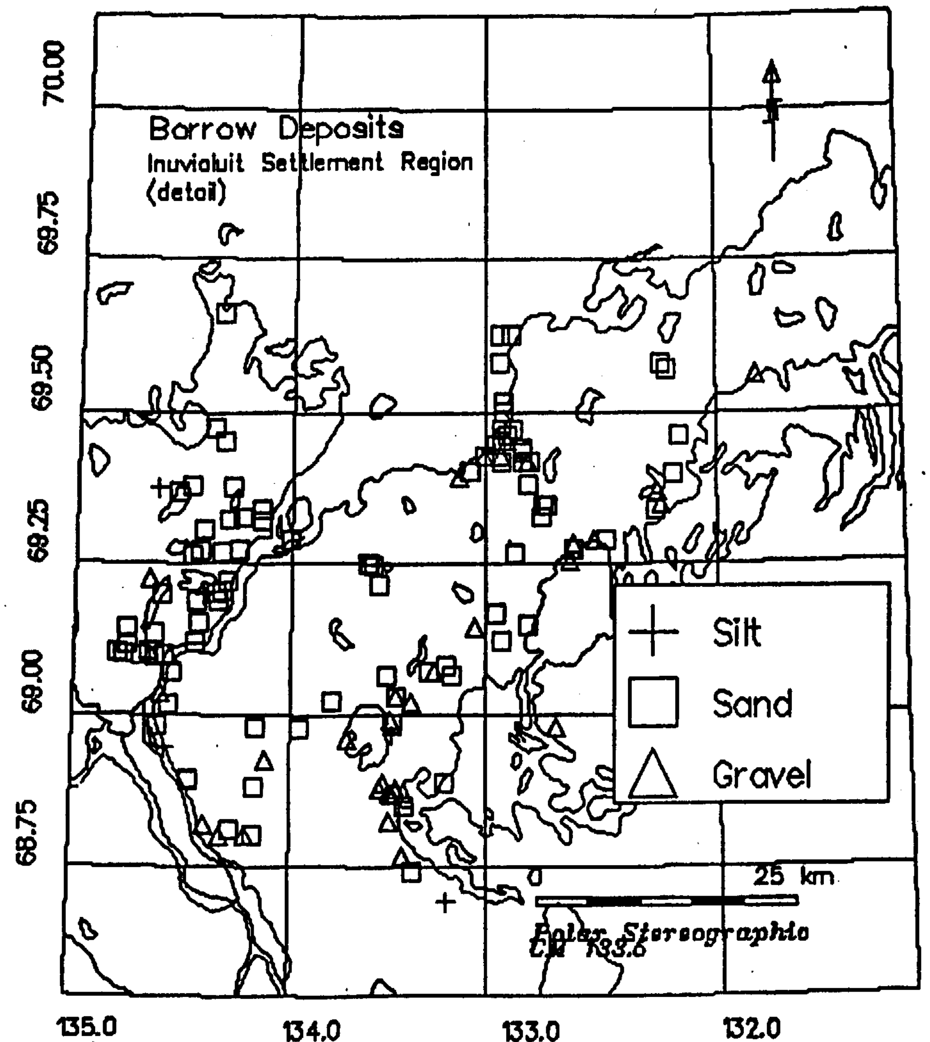
Borehole location points contain data base reference information such as the project number, date, client, location in UTM and Lat/Long, water depth and borehole termination depth.

FIGURE 2



The Isserk Block resource potential displayed with depth to deposit surface from mean sea level.

FIGURE 3



Borrow deposit information is available for much of Canada's North West Arctic region. Individual sample points are backed-up with data base information regarding the source reference, year, location in UTM and Lat/Long, granular type and USC classification.

FIGURE 4

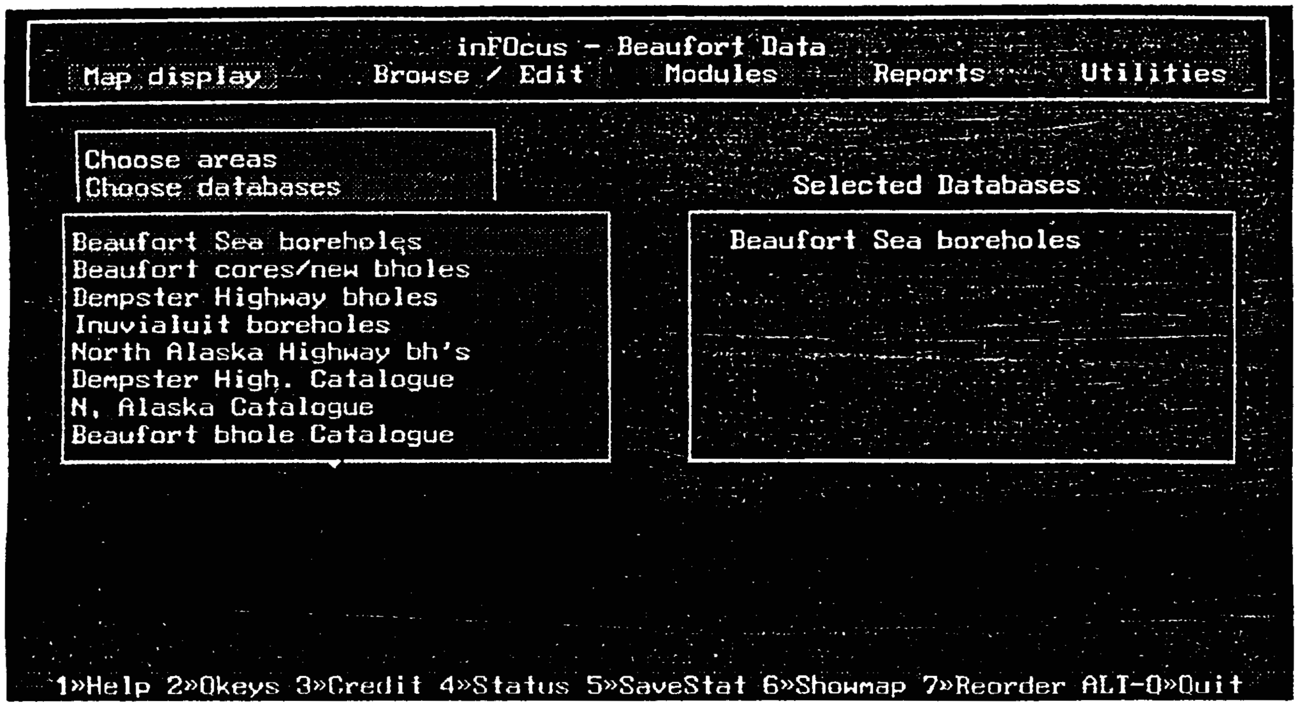


FIGURE 5

Databases menu in inFOcus. Databases are referred to by "English" aliases, thus insulating the end user from the need to remember cryptic filenames.

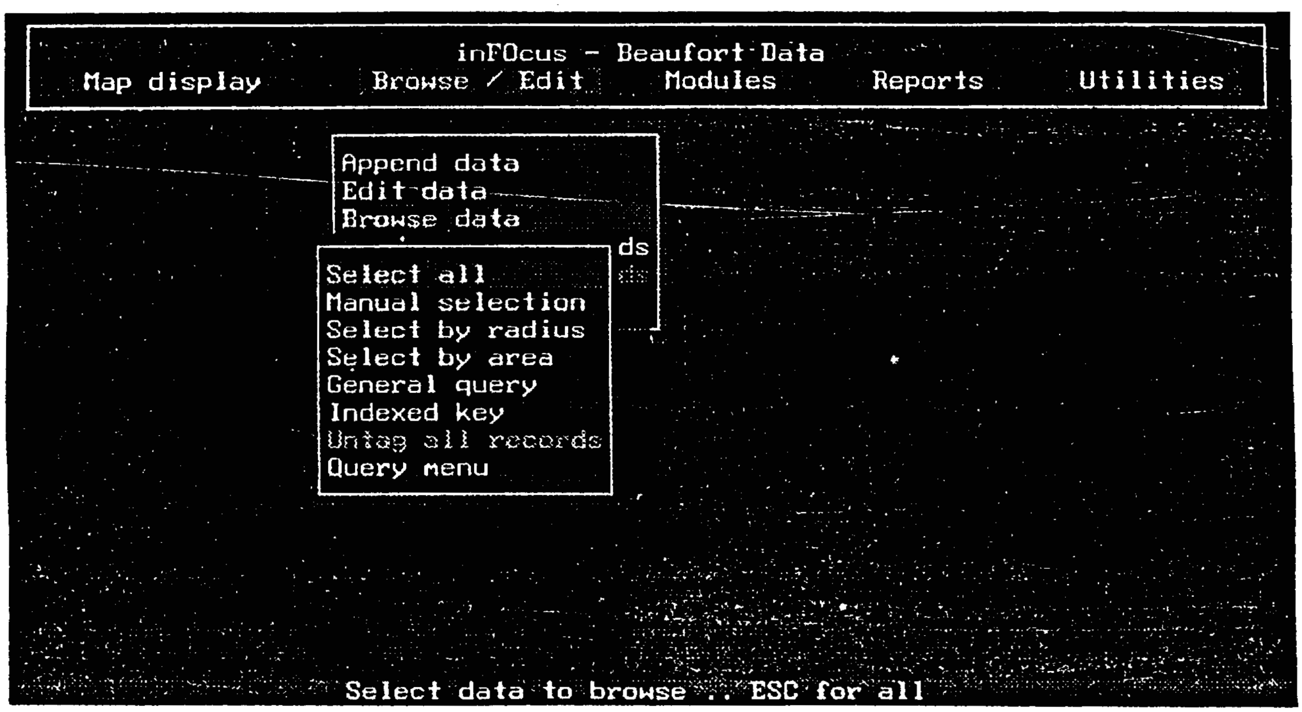


FIGURE 6

Databases can be searched in a variety of routine ways, in addition to general queries that are constructed through a mouse driven query interface.

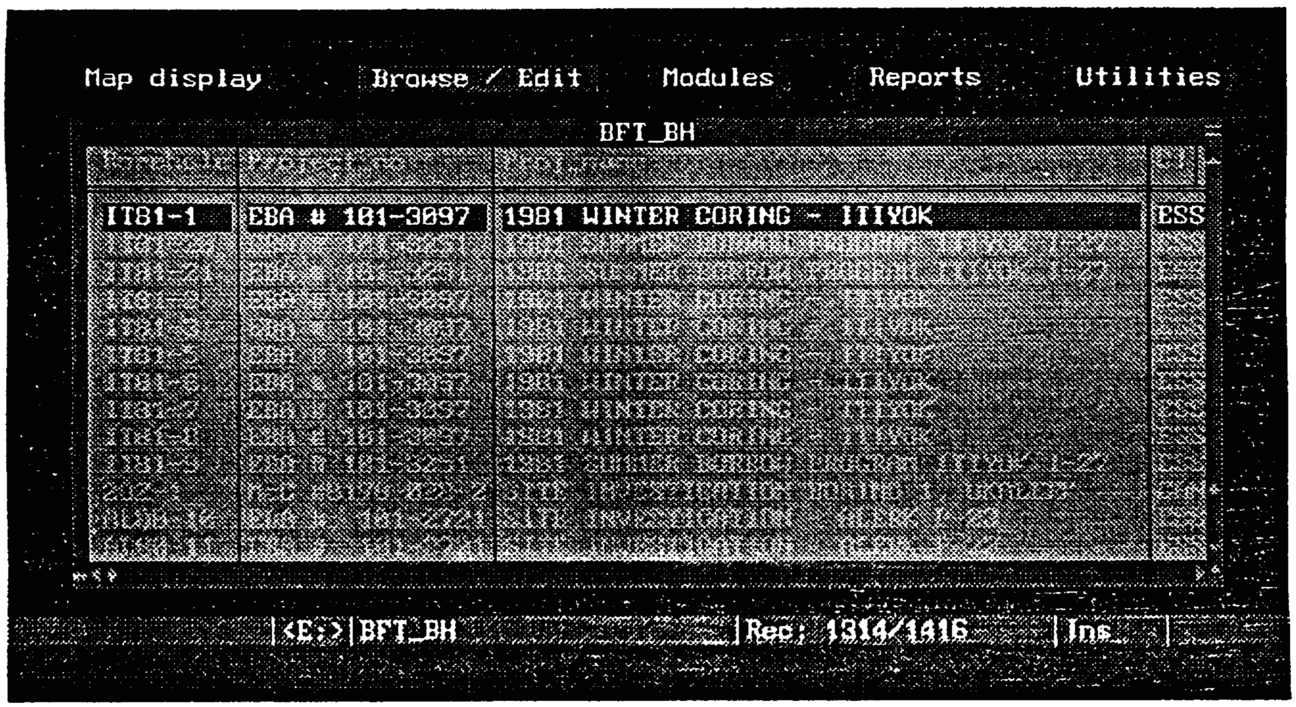


FIGURE 7

The results of queries can be browsed within a movable, sizeable browse window. Here the 1416 boreholes compiled to 1988 are shown.

Geotechnical and Geophysical Data Bases

Presented By Rita I. Olthof
EBA Engineering Consultants Ltd.
Yellowknife, N.W.T.

1.0 Introduction

In 1988, EBA Engineering Consultants Ltd. (EBA) compiled a geotechnical report catalogue and a data base of 1,288 borehole logs completed in the Canadian Beaufort Sea between 1973 and 1987. In 1989, the data base was expanded to include 1,053 surficial sediment corehole logs completed prior to 1988 and 46 borehole logs completed in 1988. In 1991, the geotechnical data base compiled by EBA was expanded and a geophysical data base compiled in 1988 by McElhanney Geosurveys Ltd. was expanded. Logs compiled in 1991 include 80 relatively deep boreholes or coreholes and 334 surficial sediment samples. To date (as of 1991), a total of 2,801 logs have been compiled in the data base. The assignments were carried out for Indian and Northern Affairs Canada (INAC), under funding provided by the Northern Oil and Gas Action Program (NOGAP).

Amoco Canada Petroleum Ltd. (Dome/Canmar), Esso Resources Canada Ltd., Gulf Canada Resources Ltd., the Geological Survey of Canada (GSC), Indian and Northern Affairs Canada and the Canadian Hydrographic Service (CHS) have provided valuable data for the data base. Although the data base now includes over 2,800 log entries, it is not yet complete. Five borehole logs from the GSC data base, which were incomplete, were not included in the data base. Twelve logs are available from Amoco which have not yet been included. Also, there are estimated to be several hundred more shallow corehole logs available at GSC from the 1970 and 1971 M.V. Hudson Surveys which should be included in future additions to the data base. Several geophysical reports were not obtained; one from Gulf (1990 program) and the remaining reports from Esso. The now-defunct organizations Arctic Petroleum Operators Association and Beaufort-Delta Oil Project Ltd. also have numerous reports which, thus far, have not been obtained or checked for relevant information.

Including work done in 1991 by Indian and Northern Affairs Canada, the data bases now comprise a report catalogue, an ESEBase borehole data base and a source data base which describes specific sources of granular materials. These data bases are linked by use of common granular source numbers, study numbers and UTM locations. Information contained in the data bases can be (and has already been) used to evaluate as much as possible of the available geophysical and geotechnical data in the Canadian Beaufort Sea, primarily with respect to quantifying the locations and volumes of proven, probable and prospective granular resources. Some evaluation projects conducted to date using the data bases are presented at this seminar/workshop including the Isserk and Erksak Borrow Site study programs (presented by John Lewis of Lewis Geophysical Consulting) and a regional surficial geology program for the South Central Beaufort Sea region (presented by Steve Blasco of the Atlantic Geoscience Centre).

Table 1 summarizes the numbers and type of logs compiled in each year of the project. Table 2 summarizes the numbers of reports reviewed in each year and the range of dates of the reports.

It is our understanding that the report catalogue is available from INAC on an as-requested basis in digital or paper format. The ESEBase borehole data base has a more restricted distribution. A sub-set of the ESEBase borehole data base has been extracted by INAC for borehole location mapping purposes and consent was obtained from the operators for use of this general information. The detailed information remains protected and confidential, with the exception of future by the Geological Survey of Canada (GSC), whose purpose is scientific.

2.0 Project Outline

2.1 Objectives

The primary objective of the work has been to compile, in a standardized (ESEBase) format, a data base of surficial sediment core and deep borehole data from the Canadian Beaufort Sea. The data base is intended for use in the evaluation of granular resources for construction materials. The data base logs are intended to be accurate, stratigraphic and textural interpretations of the originals; however, some detailed engineering (for example, strength, consolidation, etc.) data has been omitted.

A second significant part of EBA's work has been to compile a bibliography or report catalogue of the various operator and consultant reports containing sub-surface geotechnical information. In 1991, existing geotechnical and geophysical report catalogues (compiled in 1988 by EBA and McElhanney, respectively) were updated to reflect additions made to the data base in 1989 and 1991.

2.2 Data Presentation

A report catalogue sample entry is presented as Figure 1. Geotechnical and geophysical information for the data bases was obtained from a total of 148 reports. This number is somewhat misleading as some reports cover larger geographic areas than others. For example, some reports may contain only one or two boreholes at a single site, others may contain over 200 holes dispersed over a large area. Therefore, in order to facilitate searching for this data, the catalogue of field activities includes 179 entries with separate entries for 'sub-projects' from smaller geographic zones.

3.0 Data Base Description

The Beaufort Sea data base was originally prepared with ESEBase Version 3.0. ESEBase Version 4.0 is now available. All files created with Version 3.0 are upwardly compatible, with a one-time conversion when the data base is first used. Figure 2 presents a typical borehole log, as produced by the ESEBase program.

The difficulty in preparing a large data base or series of data bases from almost 150 different reports is with standardization. The original format, numbering system, datum, etc., were generally not consistent for the raw borehole data received for many logs; thus, some modifications were required to standardize the logs to ESEBase format for inclusion in the present data base. There was also a need to standardize borehole name formats for coding into the system. Thus, as shown in Table 3 and Figure 3, a borehole code would include a code for area location, year drilled, type of sample and borehole number. Borehole logs themselves were standardized according to sample types (for example, core, SPT, Shelby tube), datums were referenced to seabed, soil description (order of priority of terms), soil classification and ground ice descriptions.

3.1 Soil Description

The stratigraphic information on the logs includes the following components (also summarized as Figure 4) where available.

- Principal component (e.g., clay, sand, silt, etc.).
- Unified Soil Classification (USC).
- Principal component modifier(s) (e.g., silty, some sand, etc.).
- Particle shape.
- Structure.
- Moisture.

- Consistency.
- Plasticity.
- Colour.
- Ground ice description.

It should be noted that soil strength parameters were generally not included in the original versions of the ESEBase data base, except in a few cases where the original borehole logs were already in ESEBase or ESELog and required little modification to standardize. However, at the request of Indian and Northern Affairs Canada, some original borehole logs including strength data were provided (May, 1988) after data base completion. Therefore, the strength data is readily accessible for addition to the data base at some later time.

3.2 Soil Classification Data

Moisture content, Atterberg Limits, limited grain size analyses and Unified Soil Classification (USC) data have been included in the data base. Atterberg Limits and grain size analyses were used to check and provide Unified Soil Classification System (USC) classifications. All available grain size data has been included in the data base. 'D50' data was not available for the logs and was not calculated due to time constraints. This data would be a valuable addition to the logs. Silt and clay contents are presented in separate fields in the 'Basic Soil Characteristics Data' file.

3.3 Ground Ice Description and Sample Temperature

The ground ice description standard used for this data base follows the guidelines established by NRC. Where available and readily interpreted, ground ice information and soil temperature has been recorded in the ESEBase borehole data base.

4.0 Computer Data Handling Routines

For some similar on-shore data bases, computer data handling routines were required to extract data from ESEBase files and update the granular resource (source) data base maintained by INAC. All data for boreholes, testpits or exposures for a given source/study number was extracted from ESEBase files. The parameters needed for the source data base were then calculated and the source data base record was either updated (for existing entries) or created (for new entries). When the granular sources and their boundaries are better defined, the same operation can be done for the Beaufort Sea data bases to create a source data base.

5.0 Use of the Data Bases

The report catalogue is useful for determining what has been done in a specified area. For example, in dBase, a listing of all reports with a specified UTM zone, minimum and maximum northing and easting can be made, and/or a report catalogue summary sheet can be printed for each relevant report. The report catalogue summaries give information regarding contact names for the project, study type, size and quality of data, level of detail and so on. The researcher could then refer to ESEBase borehole data base for further details or obtain the original reports themselves.

In ESEBase, print-outs of actual logs from a specified area can be made, as well as profiles or stratigraphic cross-sections through the area, maps of borehole locations and plots of laboratory data. Or, for example, if one wanted a plot of all areas with a soil of gravel content of 20% or more, ESEBase could sort and select the required boreholes for plotting. One can also sort boreholes by operator.

When constructed, a source data base could be used similarly. For example, for a specified area, further details on soils in the area including numbers of boreholes, type and thickness of overburden, details on proportions of gravel/sand/fines in the granular resource and test result summaries can be obtained. This data base will summarize data found in the ESEBase borehole data base.

Plots can also be made in conjunction with other software programs, for example, inFOcus and Quikmap are used. Further development is being undertaken for easier use of these programs in conjunction with ESEBase. John Peters' presentation discusses this aspect further.

6.0 Closure

In total, 2,801 corehole, borehole and surficial sediment logs from the Beaufort Sea have been summarized in a data base intended to allow interpretation of the distribution of granular resources and restrictions on their development. In the future, logs not yet included in the data base could be added. Regular maintenance of the data base by updating annually with new borehole data will provide a reliable source of data on Beaufort Sea granular resources.

It should be realized that some errors in the data bases are inevitable. Also, the data can only be as good as the original data source, which may vary according to weather and/or sampling conditions. Therefore, use should be for information purposes only and confirmation of original reports or independent confirmation should take place as required on a project specific basis.

Table 1
Summary of Boreholes and Surficial Sediment Samples

Year of Compilation	Number of Boreholes/Samples For Each Operator							
	Amoco	Esso	Gulf	GSC	INAC	Chevron	Sunoco	Total
1988	302BH	816BH	165BH	-	5BH	(147BH)		**1288**
1989	45SS	460SS	387SS 46BH	114SS 46PC 1BH			**1099**	
1991	99SS	13BH	235SS	65CH				**414**
TOTAL	**446**	**1289**	**835**	**226**	**5**			**2801**
Total Not Included	12BH		2BH* 6GC*	5BH& MV HUDSON#		147BH		172

*• Gulf data not released for use.
& Boreholes with insufficient data.
# Number of M.V. Hudson cores unknown, not included in total.

Abbreviations in order of appearance in table:

BH	Borehole	SS	Surficial Sediment Sample
PC	Piston Core	CH	Corehole
GC	Gravity Core		

Table 2 - Summary of Reports Reviewed

Year	Number of Reports	Year of Reports
1988	87	(1973-1987)
1989	17	(1981-1988)
1991	44	(1970-1990)

Table 3
Exploration Block Names and Abbreviations (Portion of)
(Includes 1988, 1989 and 1991 Work)

Block Name	Abbreviation
Aagnerk	AA
Adlartok	AD
Amauligak	AE, AW, AF, AM
Akpak	AK
Alerk	AL
Angasak	AN
Aok	AOK
Arnak	AR
Amerk	AS
Baillie Island	BI
Nerlerk (Borrow)	BNR
Blow River	BR
Tingmiark (Borrow)	BTN
Tarsiut (Borrow)	BTAR
East Amauligak	EA
Arksak Borrow	EK
Emerk	ERK
Irkaluk (Foundation)	FIRK
Natiak (Foundation)	FNAT
Nerlerk (Foundation)	FNR
Garry Island	G, GI
Herschel (Borrow)	HB
Herschel Island	HI
Hooper/Pelly Region	HP
Isserk (Borrow)	IB
Isserk (I-15)	IR, 1SRK
Issigak (Borrow)	IBS, IK, ISGK
Immerark	IE
Igaluk	IG

BEAUFORT SEA
INDIAN AND NORTHERN AFFAIRS CANADA
CATALOGUE OF GRANULAR RESOURCE-RELATED INFORMATION

STUDY NUMBER: D-82-002 MONTH: 7 YEAR: 1982

SPONSOR : AMOCO CANADA PETROLEUM CO LTD. (DOME,CANMAR)
JOB NO : CONTACT: K. Hewitt
CONTRACTOR : EBA Engineering Consultants Ltd. and McClelland Engineers, Inc.
JOB NO : 101-3605 CONTACT: MR. KEVIN JONES
REPORT TITLE: 1982 OFFSHORE GEOTECHNICAL SITE INVESTIGATION, BAILLIE ISLAND GRAVEL SEARCH, BEAUFORT SEA

COORDINATES :	MINIMUM	CENTRE	MAXIMUM
UTM: ZONE:	8	0	8
EASTING:	512180	0	584090
NORTHING:	7765050	0	7885520
OR: LATITUDE:	0.00000		0.00000
LONGITUDE:	0.00000	0.00000	0.00000

LOCATION:

	GENERAL LOCATION	SITE PLAN
NAME :		Baillie Island
NUMBER:	1,A.1,A.2	1,A.1,A.2
SCALE :	1:2272727	1:2272727,270270,675
FORMAT:		
ARCHIV:		
DIG NO:		

SOURCE NUMBER(S):

SURVEY LINES / LOCATION DETAILS:

DESCRIPTION OF STUDY AND SURVEY DETAILS:
TYPE : dredging
SCOPE: 1 site
LEVEL: stratigraphy, delineation

SIZE : 22 clam-shell samples
SURVEY PATTERN: random
SURVEY SPACING: random
SEASON: summer PROGRAM LENGTH:

EQUIPMENT : clam-shell sampler, bucket dredge sampler

PENETRATION: seabed surface

RESOLUTION : good

INFORMATION ON SAMPLES OR SURVEY RECORDS:
RATE : N.A.
QUALITY: disturbed
TYPE : clam-shell samples
SIZE : 22 grab

LEVEL OF DETAIL: INTERPRETATION/ANALYSIS/REPORTING:
INTERP : grain distribution
REPORT : summary/data compilation report
DISTRIB: sponsor/contractors
OTHER :

ARCHIVING OF INFORMATION:
REPORT :
DATA : sponsor/contractors

DATA COMPILATION AND UPDATING:
COMPILED BY:
DATE : 88/03 COMPILATION PROJECT NO.:
UPDATED BY : EBA ENGINEERING CONSULTANTS LTD.
DATE : 91/03/27 UPDATE PROJECT NO.: 0306-34693

REPORT CATALOGUE SAMPLE FORM

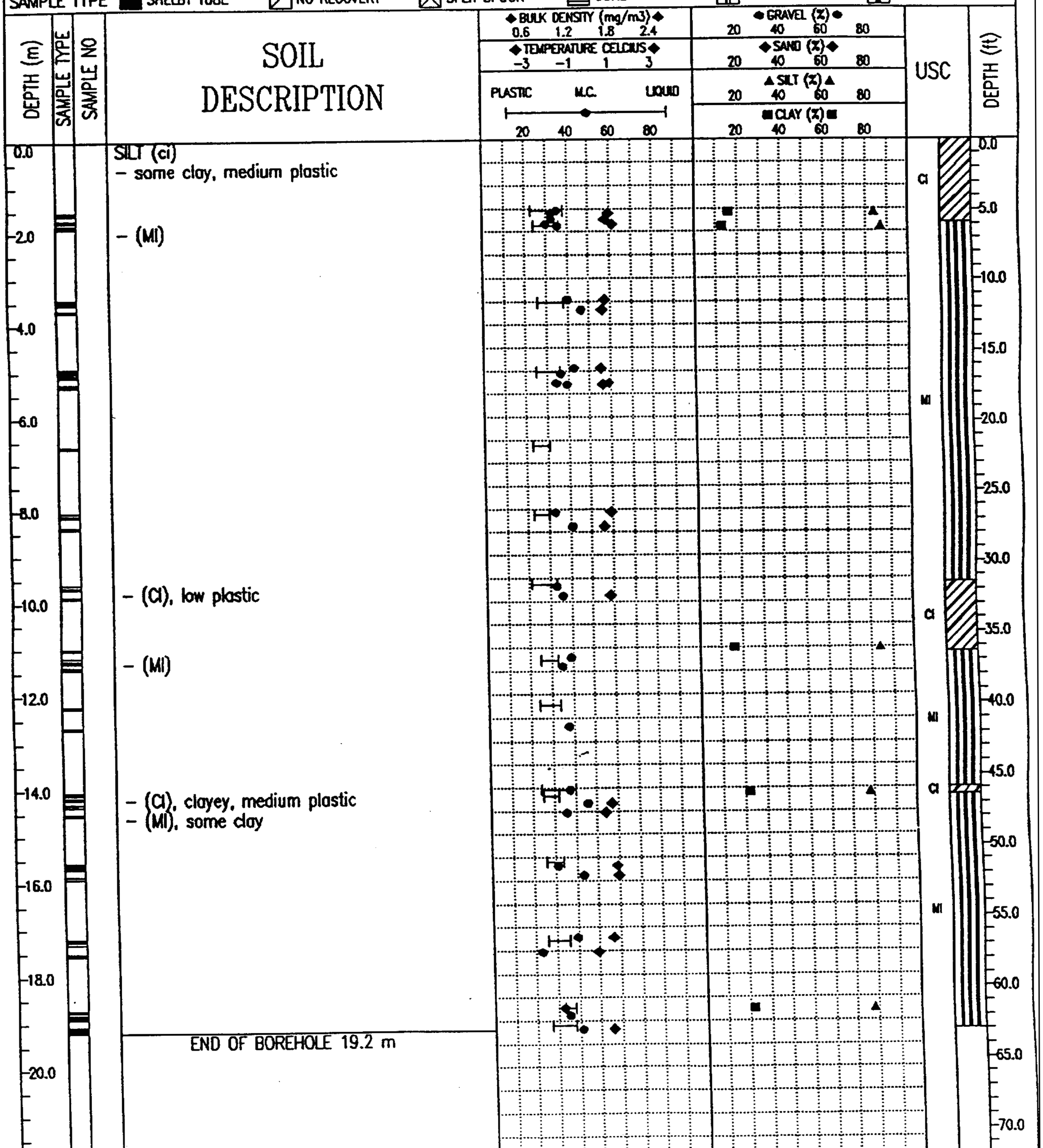
FIGURE 1

TYPICAL ESEBASE BOREHOLE LOG

FIGURE 2

BELUGA BAY 1984	DEPTHS ARE REFERENCED TO SEABED.	TESTHOLE No. UK84TT01
GEOLOGICAL SURVEY OF CANADA	WATER DEPTH – UNKNOWN	Project No:
ORIGINAL BOREHOLE NO. BH 0 + 00	UTM ZONE: 8 N7728586.00 E516967.00	ELEVATION 0.00 (m)

SAMPLE TYPE: SHELBY TUBE / NO RECOVERY / SPLIT SPOON / CORE / SHIPEK GRAB / GRAVITY CORE



EBA Engineering Consultants Ltd. Calgary, Alberta	COMPLETION DEPTH 19.2 m	COMPLETE 84/ /	
	LOGGED BY	DWG NO.	Page 1 of 1

FIGURE 3 TYPICAL BOREHOLE/COREHOLE/SAMPLE NUMBER

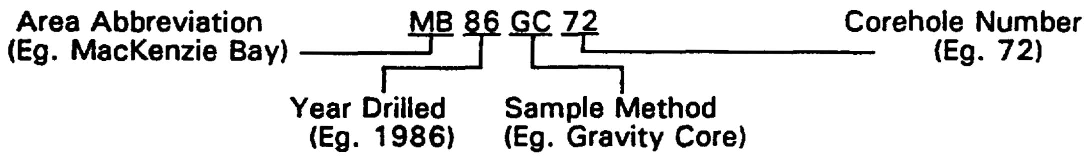


FIGURE 4 SOIL DESCRIPTION

- principal component (e.g. CLAY, SAND, SILT, etc.)
- Unified Soil Classification (USC)
- principal component modifier(s) (e.g. silty, some sand, etc.)
- particle shape
- structure
- moisture
- consistency
- plasticity
- colour
- ground ice description

Real-Time Interpretation of Marine Resistivity

Presented By W.J. Scott
Centre for Cold Ocean Resources Engineering
Memorial University of Newfoundland

1.0 Introduction

This paper describes the development of a real-time interpretation capability for the MICRO-WIP marine resistivity system. The program was carried out in 1987 by Hardy BBT Ltd. for Indian and Northern Affairs Canada (INAC). Scientific Authority for the project was Mr. R.J. Gowan of INAC. W.J. Scott of Hardy BBT was the project leader.

The detection of sub-bottom permafrost and granular deposits is very important for the design and construction of off-shore facilities in the Beaufort Sea. Granular deposits will supply valuable borrow material for construction of islands while the presence of permafrost will influence the choice of routes and construction of pipelines.

In 1980, Hardy Associates (1978) Ltd. (now Hardy BBT Ltd.) began the development of the marine resistivity system known as MICRO-WIP, (MICROprocessor controlled Waterborne Induced Polarization). In various stages of development, this system was used for fresh water work in mineral exploration and for salt-water searches for granular materials. Initial results of a survey off-shore Alaska were described by Scott et al., 1983. At that time, design of the system was relatively established and only minor changes were made from then until the commencement of the program described in this paper. The system was used in the Canadian southern Beaufort Sea in 1985 in a successful program to map granular materials for island construction (Scott and Maxwell, 1989). In this survey, it was felt that a major limitation to the 1985 system was the lack of a real-time resistivity interpretation capability.

In 1977, with INAC funding, the existing marine resistivity system hardware and computer software were redesigned to incorporate real-time interpretation of the resistivity data. The system was assembled and bench tested prior to carrying out a field trial. Descriptions of the equipment design, bench tests and field trial results are presented in this report. Since the 1987 INAC program, the MICRO-WIP has been transferred to a PC-based system, which is also briefly described in this paper.

2.0 Background

The use of electrical resistivity measurements has long been accepted on land as a means of mapping the distribution of granular resources and permafrost (Scott et al., 1979). In general, electrical resistivity of soils is a function of grain size, with sands and gravels having a higher resistivity than silts and clays. This relationship holds even when the pore water in the materials is saline. Furthermore, frozen materials have much higher electrical resistivities than the same materials in an unfrozen state.

Figure 1A, after Scott and Maxwell (1989), shows values of electrical resistivity for some typical soils on land as a function of temperature. From this figure, it is clear that freezing the soil generates a drastic increase in its resistivity. Figure 1B shows the range of resistivity values for typical soils on land. The higher the resistivities observed in soils, the more coarse-grained those soils are likely to be, provided that temperature and moisture content conditions are similar. A similar relationship prevails for seabed materials, although the actual resistivity values are smaller. Results of the 1991 survey, as yet unpublished, indicate that increasing gas content in a soil increases resistivity as well.

2.1 Resistivity Measurements

Measurement of resistivity on land or water involves injection of electrical current through two electrodes and measurement of the resulting potentials between other electrodes. A quantity known as apparent resistivity is calculated from these measurements in the following manner:

$$\rho a = (V/I) * f(G)$$

Where: ρa = apparent resistivity.
I = the injected current.
V = the observed voltage.
f(G) = a function of the geometry of the electrodes.

If V is in volts, I is in amperes and the distances in f(G) are in metres, then the units of ρ are ohm-metres (Ω-m).

If the ground under the electrode array is homogeneous to a depth much greater than the size of the array, then the measured apparent resistivity would be equal to the true resistivity of the earth. Such a uniform case rarely occurs in nature, the apparent resistivity usually represents some function of the distribution of values in the earth within the range of the measurement.

The general procedure in making electrical resistivity measurements involves varying the size of the array and thus, the volume of ground affected by the measurement and observing changes in apparent resistivity as a function of this variation. The resulting set of observations is called a sounding.

The array most commonly used in marine resistivity is the multi-dipole array. For this array, an increase in depth of penetration is normally accomplished by increasing the spacing between transmitter and receiver dipoles, while keeping the dipole size constant. The expansion of array sizes is carried out in terms of the dipole multiple "n". The smallest array is with n = 1. In this case, the distance between the nearest transmitter and nearest receiver electrode is one dipole length. Increased penetration is achieved by increasing the number of dipole lengths separating transmitter and receiver dipoles. In practical field situations, the largest separation normally achievable is limited by signal strength to n = 6. Thus, a multi-dipole sounding consists of six apparent resistivities calculated for n = 1 to 6.

2.2 Interpretation of Resistivity Measurements

Once a set of apparent resistivity values has been measured, interpreting the results of electrical surveys to identify granular materials or permafrost is a two-part process. The first part is obtaining a model which fits the observations, the second part is making the correlation between the model parameters and the type of soil to be expected.

Resistivity models are described by layer thicknesses and resistivities. In the case of a multi-dipole sounding, the apparent resistivities for n = 1 to 6 can be used to develop simple models involving the water and two sub-bottom layers lying on a half space. The resistivity and thickness of the water can be determined by independent means. Sub-bottom materials can be modelled in terms of two layers lying on a half space. In areas where granular materials are expected to be close to the bottom, variation of resistivity in these upper two layers would be indicative of variation of grain size in the near sub-bottom.

The parameters of the model are obtained from the measured apparent resistivities by an inversion process. A first estimate is made of the model resistivities and thicknesses and the apparent resistivities which would be observed for this model are calculated. These resistivities are compared with those observed in the field and adjustments are made in the model parameters in the direction which minimizes the disagreement between observed and calculated apparent resistivities. Normally, several cycles of calculation and adjustment will bring the calculated and observed apparent resistivities into reasonable agreement, provided that a good initial model is used.

It should be understood that it is frequently possible to obtain more than one model which will satisfactorily match the observed apparent resistivities. Thus, it is important that the starting model be reasonably close to the situation which is being investigated. External control such as drillhole information, sub-bottom profile information and geological inference can thus be used to help sharpen the precision of the geophysical interpretation.

2.3 Measurement Techniques for the MICRO-WIP

Marine resistivity measurements with the MICRO-WIP system are made by means of a streamer towed behind a survey vessel. This arrangement is shown schematically in Figure 2. The multi-dipole array is incorporated into the streamer. The two electrodes nearest the survey vessel are used to transmit electrical current into the water and sub-bottom materials. The other seven electrodes on the streamer are used to measure the resulting voltage distribution as a function of distance from the source and consequently, as a function of penetration into the sub-bottom. These seven electrodes allow the calculation of the six values of apparent resistivities as discussed above. Experience in the Beaufort Sea in 1985, indicates that a current of 15 amperes is adequate to give reliable signal levels for measurements of this sort with a dipole length of 25 m and separations of $n = 1$ to 6.

2.4 1985 MICRO-WIP Survey, Southern Beaufort Sea

During the summer of 1985, the system was operated in the Beaufort Sea to map resistivities in support of evaluation of granular resources (Scott and Maxwell, 1989). This survey was carried out prior to the dredging of material to build an artificial island. Despite very bad ice conditions which allowed only very limited access to the survey area, some 40 km of survey data were obtained during a two day period. After completion of the survey, however, a ten day period elapsed before the first preliminary interpretation was provided to the client. A further period of a month ensued before presentation of the detailed interpretation.

Fortunately for the future of MICRO-WIP, other geotechnical information had already indicated the presence of granular material and the borrow pit was successfully established shortly after the preliminary interpretation was supplied. The final interpretation showed that the borrow pit was indeed in the optimum location.

From the 1985 survey several things emerged. The first was the need for real-time processing in order to avoid delay in providing interpretation. The second was an understanding of the general range of resistivities to be expected in the sub-bottom materials. These resistivities correlated reasonably well with those initially determined by Scott (1975) in resistivity soundings carried out through the sea ice in the same general area. The 1985 survey further provided some observed values of apparent resistivity as a function of dipole spacing which could be used in simulated trials with modified equipment.

It was in light of this experience that the 1987 INAC development program was undertaken. The objective of this program was to develop the capability to carry out interpretation in real-time, in order that reconnaissance surveys could be performed shortly before dredging, with interpretations produced shortly thereafter.

3.0 System Design and Testing

To provide real-time interpretations, two functions had to be developed within the system. The first of these was the averaging of the digitized wave forms and calculation of apparent resistivity values. The second was to invert the apparent resistivity values in terms of a three-layer model. Within the time constraints of real-time processing, it did not appear possible to perform both functions in a single computer. It was, therefore, decided to carry out the first function within a data acquisition system (DAS) and the second in the computer which controlled the DAS.

A Hewlett Packard HP 3852 data acquisition and control system was selected. The system could be configured for a variety of applications. It had built-in intelligence, an internal clock and a programmable pacer which could be used as timing control for remote devices. A controller was built to turn the transmitter on and off in synchronization with the timing supplied by the pacer signal in the HP 3852. A Hewlett-Packard 9816 computer was selected to drive the DAS and to run the inversions.

To test the system in the laboratory, a resistance network was devised to simulate a streamer in the sea. With this network and a very low-powered transmitter, bench tests were conducted to refine the performance of the real-time inversion routines.

Finally, the entire system was installed on a suitable vessel for a field trial on Okanagan Lake, British Columbia. There the real-time resistivity interpretation capability of this system was demonstrated during the field trial.

Two computer programs were developed to run the system. Both of these have now been superseded by the PC-based programming and thus, will not be described in detail here. The first program down-loaded a set of instructions to the DAS to set up the system pacer, scan the amplifier channels, stack the voltages and check the gains. The main program initialized the plotter, started the DAS, read data from the DAS, ran the inversion and plotted the real-time resistivity section.

In the 1991 system, the DAS has been replaced by a set of data acquisition boards installed in the PC, which stack the incoming signals and store the results directly in memory. The PC then uses these values to calculate the apparent resistivity and chargeability values. At present, the system does not have the real-time inversion implemented, but the programming is structured to include inversion and the routines developed in 1987 will be incorporated in the near future.

4.0 Choice of Electrode Array

The 1985 survey was performed with an array of 25 m dipoles and n = 1 to 6. This array was initially designed for mineral exploration, where arrays with constant dipole size are common. The combination of water depth, water resistivity and sub-bottom conditions in the 1985 Beaufort Sea survey area was such that the 25 m array gave good definition of the surface layers and at the same time, adequate penetration to map relic permafrost at depth.

Subsequent computer modelling supported by an Industrial Research Assistance Program (IRAP) Grant suggested that better resolution of deep features and better definition of near-surface resistivities could be obtained with an array in which the receiver dipole size increased logarithmically with distance from the transmitter dipole. As part of the IRAP program, such a streamer was built. The spacings of this streamer are given in Table 1.

Because the 1985 data were taken with constant dipole lengths, the simulator network was established for this configuration, but the data acquisition system and inversion routines were configured to handle either constant-spacing arrays or logarithmic-spacing arrays.

Table 1 - Logarithmic Streamer

Distance (m)	Identification	Electrode
0	Start of Cable	
		C1
25		
	Current dipole	
50		C2
60		P1
	Potential Channel 1	
70		P2
	Potential Channel 2	
85.75		P3
	Potential Channel 3	
107.75		P4
	Potential Channel 4	
141.25		P5
	Potential Channel 5	
189.25		P6
	Potential Channel 6	
260.50		P7

5.0 Simulation of Beaufort Sea Measurements

Within the time and cost constraints of the 1987 INAC program, it was impossible to collect real data from the Beaufort Sea with the modified system. It was, however, possible to predict, from forward modelling programs already in existence, the apparent resistivities that would be observed with the new system over given geologic conditions and to choose a network of resistors that would provide the appropriate signal levels.

The interpretation carried out on the data from the 1985 survey showed that the resistivity of the sea water in the southern Beaufort Sea was typically about 2.0 Ω-m (interpretations of data from the 1991 survey, over a wider area, show variations of sea water resistivity from 1 to 8 Ω-m). In electrical terms, the sub-bottom materials in the 1985 survey area could be represented by three layers. The uppermost layer appeared to have resistivities ranging from 1.6 to 2.6 Ω-m. From the limited drilling carried out to a establish the borrow pit, it appears that this range of resistivities spanned materials from clayey silts to coarse sands with occasional pebbles. Within the survey area, none of this material appeared to be frozen.

The bottom-most layer interpreted in the 1985 survey had resistivities which ranged from a low of 10 Ω-m to a high of >500 Ω-m. The variation of resistivity generally reflected the depth to the top of the layer, with the highest resistivities occurring where the layer was shallowest. A single drillhole intersected permafrost at the interpreted depth to the top of this layer within the borrow area. From the high interpreted resistivities and from the fortuitous intersection in the borehole, it was concluded that the high resistivity parts of this layer represent the ice-bonded material and that the ice content generally correlated with the interpreted resistivity values.

An unexpected outcome of the interpretation procedure was that between the uppermost layer, (1.6 to 2.6 Ω-m) and the deepest (permafrost) layer, there appeared to be a layer of significantly lower resistivity (0.5 to 1.5 Ω-m). This layer has no apparent direct geological correlation. However, work in the Alaska Beaufort Sea, (Sellmann, P.V., 1985 personal communication) suggests that there is a pronounced increase in salinity of pore waters immediately above the degrading permafrost. Such an increased salinity would result in lowered resistivities and would provide a reasonable explanation for the observations from the 1985 survey.

Table 2 summarizes the likely set of conditions which would be encountered in looking for granular materials in the southern Beaufort Sea. While this is a reasonably comprehensive set of geologic conditions, the innate perversity of nature is such that it is not possible to predict all configurations which are likely to be encountered. Furthermore, it should be realized that even with the logarithmic array, the maximum number of layers that can be resolved is three layers lying on a half space. Forward calculations can be carried for all of the models in Table 2 and a set of observed of apparent resistivities can be derived. However, in cases with more than three layers, the inversion will not necessarily lead back to the starting model. This is an intrinsic limitation of resistivity methods and must be recognized if application of marine resistivity is contemplated.

This problem, known as the problem of equivalence, can be resolved to some extent if acoustically determined boundaries coincide with some of the electrically defined boundaries. For example, it is obviously possible to define the bottom of the water (top of seabed) with a depth sounder and thus to remove the influence of the water from any model by calculation. In the case of Group 5 (Table 2), the top of the granular material under the silts and clay should constitute an acoustic reflector unless the fines are gas-saturated. In such a case, fixing the thickness of the fine-grained layer from the sub-bottom profiler record will aid in resolving such equivalences.

Table 2
Typical Sub-Bottom Geological Configurations*

Model No.	Lateral Material [ρ (Ω-m), t (m)]
1A	Granular (2.2,20)/Saline (1,20)/Permafrost (100,∞)
1B	Granular (2.2,10)/Saline (1,10)/Permafrost (500,∞)
1C	Granular (2.2,20)/Saline (1,20)/Unfrozen (10,∞)
2A	Fines (1.6,20)/Saline (1,20)/Permafrost (100,∞)
2B	Fines (1.6,10)/Saline (1,10)/Permafrost (500,∞)
2C	Fines (1.6,20)/Saline (1,20)/Unfrozen (10,∞)
3A	Permafrost(20,2)/Granular (2.2,20)/Saline (1,20)/Permafrost (100,∞)
3B	Permafrost(20,2)/Granular (2.2,10)/Saline (1,10)/Permafrost (500,∞)
3C	Permafrost(20,2)/Granular (2.2,20)/Saline (1,20)/Unfrozen (10,∞)
4A	Permafrost(15,2)/Fines (1.6,20)/Saline (1,20)/Permafrost (100,∞)
4B	Permafrost(15,2)/Fines (1.6,10)/Saline (1,10)/Permafrost (500,∞)
4C	Permafrost(15,2)/Fines (1.6,20)/Saline (1,20)/Unfrozen (10,∞)
5A	Fines (1.6,5)/Granular (2.2,20)/Saline (1,20)/Permafrost (100,∞)
5B	Fines (1.6,20)/Granular (2.2,10)/Saline (1,20)/Permafrost (100,∞)

Table 2 shows 14 likely geologic configurations, of which only 1A, 1B and 2A, the three most representative of conditions encountered in the 1985 survey were built into the physical simulator.

In order to provide a realistic transition from one of the three models to another, it was necessary to prepare a series of intermediate models so that the variation in measurement could proceed incrementally as would be the case in a field survey. Five or six intermediate steps were chosen between the three models.

A single simulator network requires fourteen resistors. The three models, with the necessary transition resistor arrays as well, represented an array of 154 resistors. Physical simulation of larger numbers of models becomes extremely difficult without a large investment in switching and resistor arrays.

The simulator starts with Model 1B (Table 2). Rotation of the selector switch moves through the transition resistors, arrives at Model 2B and then through more transitions to Model 1A. Thus with the MICRO-WIP receiver connected to the output of the simulator, it was possible, by rotating the selector switch, to simulate a survey starting in granular material on ice-bonded permafrost, passing into an area of silts and clays on ice-bonded permafrost and then on into an area of granular material on low-resistivity permafrost. Turning the switch in the opposite direction would run the simulated survey in the other sense.

Figure 4 shows parts of the survey results for a "two-way run" through the simulator. The apparent resistivities are referred to by their fiducial numbers, shown along the top of the section. Model 1B is represented by the interpreted resistivities at Fiducials 2 and 108. Model 2B is represented by Fiducials 26 and 78 and Model 1A by Fiducial 52.

It is reassuring to note that there is good agreement between the two interpretations for Model 1B,(Fiducials 2 and 106) and for Model 2B (Fiducials 26 and 52). Hence, the inversion has indeed led back to essentially the original model in each case. The interpreted resistivity of the upper layer repeats within about 1.5% and surprisingly, the resistivity of the deepest layer repeats exactly. The most poorly determined layer is the conductive (saline) middle layer, whose resistivity is interpreted to only within about 7%.

Note that the resistivities presented on the simulated data set did not match exactly the model resistivities presented on Table 2. This occurred because the current supplied by the simulation network was incorrect by approximately 10%. Since it is a constant difference, it does not affect the conclusions reached for the simulated trial.

In general, resistivity interpretations provide resistivities to a precision of only a few percent. However, the experience in the Beaufort Sea was that with slowly varying apparent resistivities, the repeatability of estimates of resistivity for near surface materials was within 2 - 5%. The variation in interpreted resistivity values as a function of grain size was in the order of 40% and thus, well beyond the likely error of interpretation.

6.0 Field Trials in Okanagan Lake

Once the system had been proven on the simulator network, it was then taken into the field for an operational trial. Okanagan Lake was chosen because it was the nearest body of water to Calgary which was of sufficient size and which was likely to be navigable during the winter time. The field trials were carried out in mid-February, 1987.

Okanagan Lake is a long lake which runs approximately north-south through the central part of British Columbia. The lake is typically 5 km wide and extends over 100 km from Penticton in the south to Vernon in the north. The test area was situated at Kelowna, B.C. Figure 5 is a location map that shows the approximate area of the lake in which the trials were carried out.

In the deeper parts of Okanagan Lake, the water depth is up to 300 m. The depth sounder operated with the MICRO-WIP system has a useable water depth of 120 m. This depth was exceeded several times during the trials. In the neighbourhood of Kelowna, there are significant areas where water depths ranged from 4 to 8 m and the bottom was relatively smooth. It was felt that the deeper water would allow an assessment of the noise level of the system in a uniform medium and the shallow areas would represent operating conditions which are similar those expected in the Beaufort Sea.

In Okanagan Lake, water resistivities are approximately 30 times greater than those of the Beaufort Sea. By the same token however, sub-bottom resistivities are also 30 times higher; the contrast between water and bottom is therefore reasonably similar to that to be expected in the Beaufort Sea.

Very little is known about the unconsolidated deposits in Okanagan Lake. However, Nasmith (1981) describes the surficial geology of sediments in the neighbourhood of the lake. From Nasmith's description, it appears that the sediments underlying the shallow portions of the test area are deltaic deposits derived from the mixed fine and coarse sediments lying above Kelowna. The shallower areas are predominantly fine grained silts and clays while granular areas are exposed on the slopes on the edges of the shallows.

Rocks exposed on shore in the neighbourhood of this survey showed intense shearing. The rocks under the lake are probably even more strongly sheared and water-saturated as well. They would, therefore, be expected to have resistivities of a few hundred ohm-metres. It is reasonable to assume that the bedrock resistivities would be in the same ratio to the shallow sub-bottom resistivities as would permafrost resistivities in the southern Beaufort Sea to the overlying sediments.

While the geology of Okanagan Lake is obviously different from that to be expected in the Beaufort Sea, resistivity contrasts from water to sub-bottom sediments to deeper sub-bottom materials should be in the same general proportions as those in the Beaufort Sea. Because resistivity interpretations deal primarily with contrasts between resistivities of layers rather than with absolute values, it is reasonable to use this area as a test site for assessing the performance of a system designed for the Beaufort Sea.

The major difference would be that in the Beaufort Sea, to obtain readings at the same level of confidence, much higher transmitter currents would be required. It is probable that currents would have to be approximately 30 times higher to compensate for the approximately 30 times lower general resistivities. The survey on Okanagan Lake was carried out with 0.5 amps while measurements in 1985 in the Beaufort Sea used 15 amps. Thus it appears that the ratio of currents used in the two settings is approximately in proportion to the ratio of the resistivities to be observed.

The primary purpose of the field trials was to establish that the modified data processing system could provide inversion of resistivity data in real-time. The field survey was thus broken into two parts. The first was to establish the noise levels in the system and demonstrate that these are low enough not to interfere with the measurements. The second was to demonstrate that the inversion technique provided answers within the real-time constraints of operating the survey.

Because of budgetary limits, a minimum set of equipment was deployed for the survey. The minimum equipment included the MICRO-WIP and an analogue-recording depth sounder with a digital output. The depth sounder was deployed in order to provide water-depth information as part of the input to the inversion process.

The budget constraints prevented the use of the sub-bottom profiler and magnetometer which normally would be part of this survey system in the field. Furthermore, because no exact geological control was available, it appeared unnecessary to employ the precise navigation system which normally would be part of the survey.

The MICRO-WIP system performed extremely well on trials with only minor modifications necessary to provide smooth functioning. The Huntec Lopo transmitter used in this survey produces an extremely noisy wave form, which was filtered to remove high-frequency components. The filtered wave form was essentially the same in character and frequency content as that which is normally obtained from the high-powered system used in the Beaufort Sea.

In this survey, for the first time, the raw data consisted of the six apparent resistivities associated with the six dipoles, normally stored on disk. Figure 6A shows a plot of the pseudo-sections of apparent resistivity and chargeability derived in the field and plotted in real-time. The beginning of the line is in deep water. This represents essentially the noise level of the system in a homogeneous medium. The end of the line is in water depths of 4 to 8 m. These resistivities and chargeabilities in mineral surveys, constitute the raw data which is recorded with the system in its present configuration. Figure 6B shows the results of real-time inversion of the raw data on a different line, in terms of a layered model.

It should be emphasized that without control, it is difficult to come to an absolute determination of the accuracy of the interpretations. However, the resistivity values and thicknesses determined for the sediments appear to be consistent with those derived from the on-shore geological model. Resistivities range from sixty to several hundred ohm-metres and the resistivity of near surface materials appears somewhat higher in areas where granular material would be expected.

7.0 Discussion and Recommendations for Future Work

The development program described in this paper resulted in a system which operated on a variety of surveys, in freshwater lakes mainly in Ontario and Quebec. The major limitation of the system was that the operator was required constantly to adjust the gain settings to avoid saturation and maintain adequate signal levels. The DAS used in the system was not capable of sufficient calculations to monitor and adjust the gains. Accordingly, in 1991, it was decided to transfer the system to an IBM-PC compatible computer and to incorporate automatic gain control. This work was completed just in time for a survey in August, 1991, funded by Atlantic Geoscience Centre, EMR, through NOGAP. Unfortunately, the real-time inversion programming had not been transferred by the time of the survey, although it is expected to be ready by the summer of 1992. The survey included side scan sonar and two sub-bottom profilers as well as the MICRO-WIP resistivity system. The results are now being compiled.

There is a relationship between lateral resolution and survey speed. One inversion is carried out for every 32 seconds worth of data. At a survey speed of 1 km/h, each sounding represents a lateral translation of approximately 9 m. At a survey speed of one knot, each reading represents a distance of approximately 16 m and at a survey speed of three knots, each sounding represents a distance of 50 m. Thus, the choice of survey speed depends upon the lateral resolution that is required in near surface features. As vessel speed increases, so does the noise level and a practical upper limit for resistivity surveying appears to be about three knots.

Lateral resolution also depends on the array size. The volume of measurement which is represented by each of the apparent resistivities depends upon the spacing between the transmitter and receiver pair which are used for the calculation. Thus, the volume involved in measurement of shallow resistivities is quite small and a movement of 50 m may involve significant lateral variation. However, for permafrost at depths of 50 - 100 m, separation between the transmitter and the farthest spaced dipole is of the order of 200 m and thus, a lateral translation of 50 m does not imply a major replacement of the volume of measurement by new material. The desired depth and resolution of the target, therefore, will have some influence on the selected speed, as it appears feasible to make reliable resistivity measurements at the speeds of up to three knots.

There is some evidence (Olhoeft, 1975) that frozen clays give rise to small induced polarization (IP) effects. The IP effect may be a useful indicator to distinguish between frozen granular materials and frozen clays. The IP effect is more noise-sensitive than the resistivity. A survey in which IP affects are measured would probably have to be conducted at a significantly lower speed than one conducted solely for resistivity measurements. It appears that with the 1987 system, realistic measurements of IP affects can only be made at survey speeds of one knot or less. Much of the present development work is concentrated on improving this noise performance.

Present research is concentrating on electrode design and on improvement of averaging processes in the programming. With improved electrodes, it is felt that reduced noise levels would allow higher survey speeds even when measuring IP effects as well.

The marine resistivity system provides information which is a valuable supplement to, but not a replacement of normal acoustic surveys. The results of the 1991 survey indicate that gaseous sediments are easily penetrated by electrical measurements and structure which is lost in acoustic profiles can be followed with electrical measurements. Incorporation of depths from seismic surveys in post-survey interpretations improves the reliability of the electrical models and thus, of the final interpretation.

There is some evidence in the 1991 survey data that gaseous sediments have elevated resistivity values. The presence of gas in pores of a soil should also give rise to increased IP effects. It is possible that gas contents can be estimated from combined acoustic and electrical surveys.

In its present form the MICRO-WIP is clearly a useful tool for the mapping of grain-size variations in near-bottom sediments in the Beaufort Sea. If geophysical mapping of granular deposits in the Beaufort Sea is to be undertaken, then consideration should be given to the use of the MICRO-WIP system.

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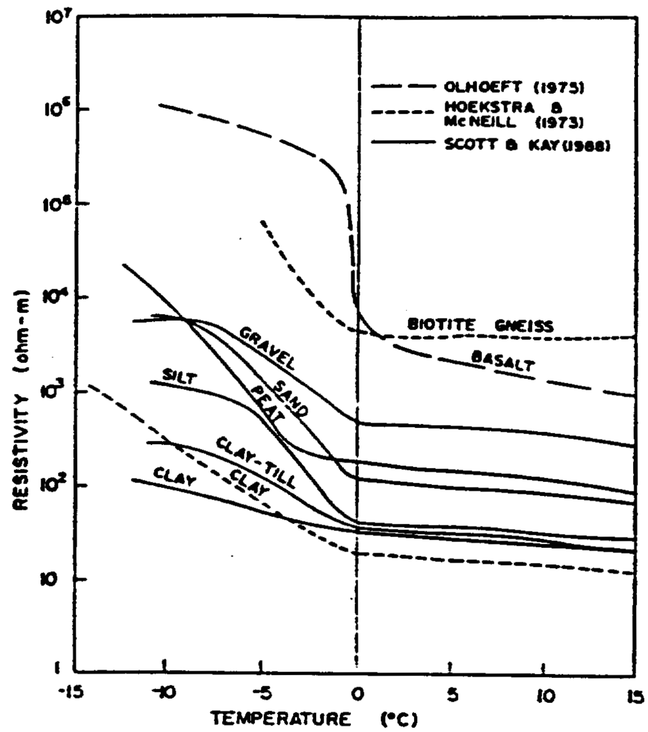

Figure 1: a) Resistivity as a function of temperature.

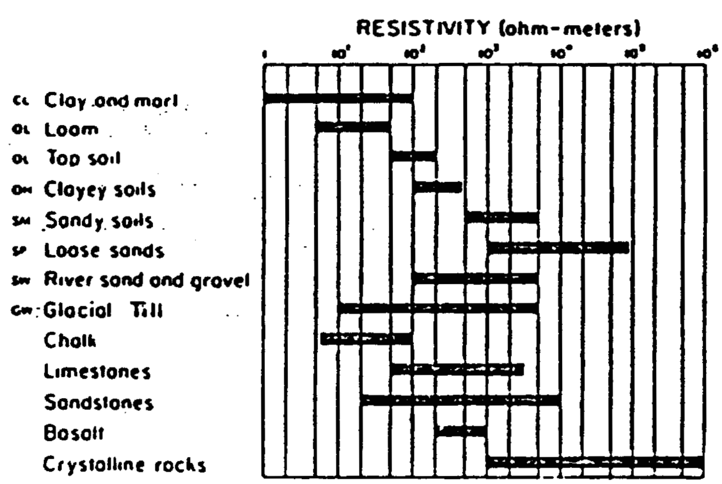

Figure 1: b) Resistivity ranges for typical soils. (Scott and Maxwell, 1989)

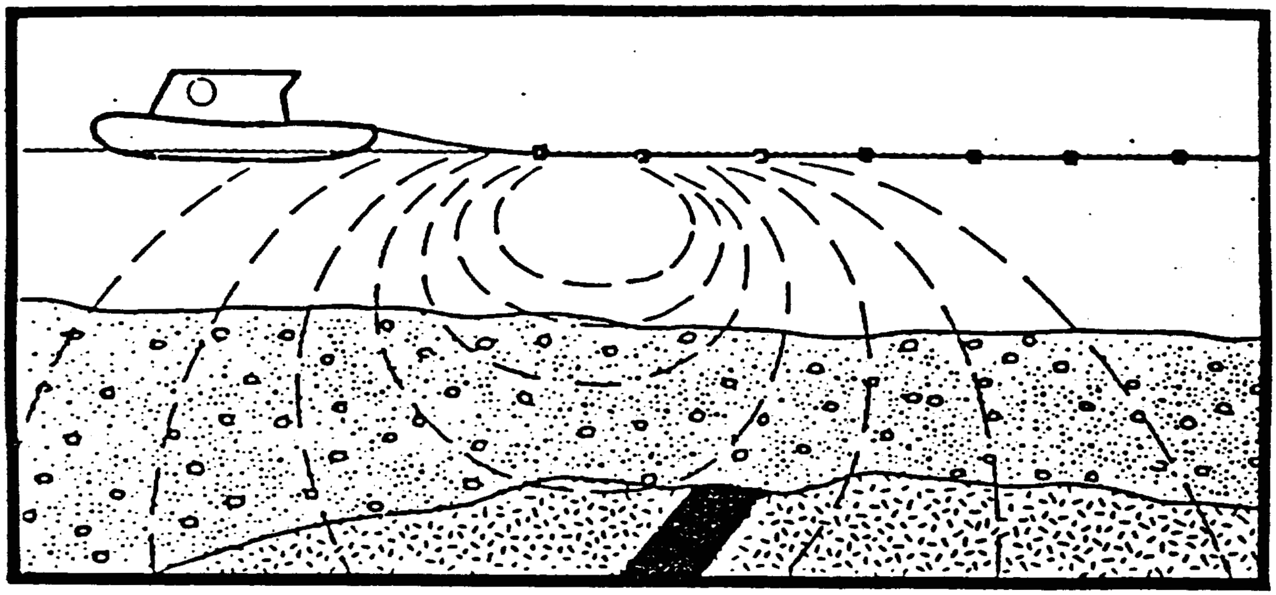

Figure 2: Schematic layout of MICRO-WIP marine resistivity system.

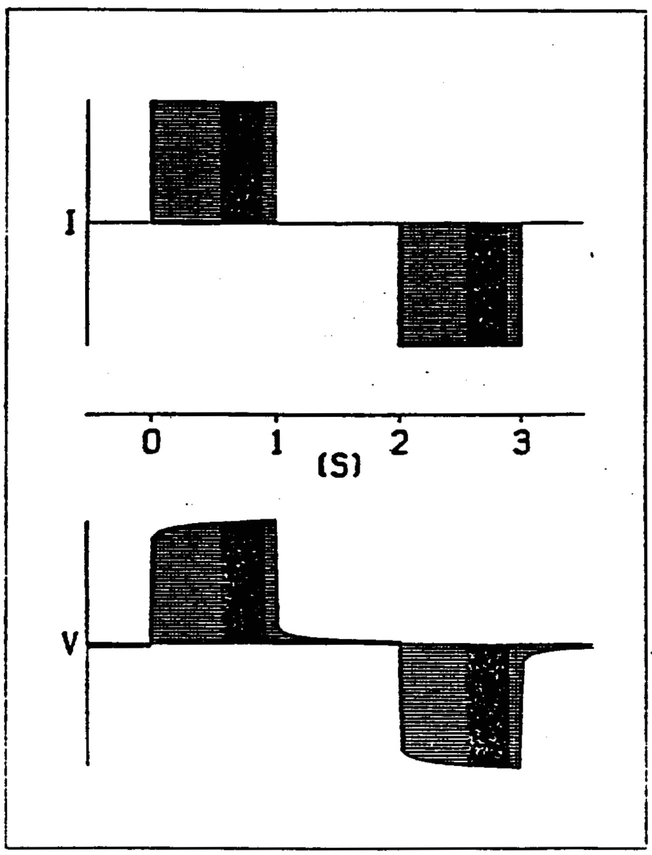

Figure 3: Waveforms of current and voltage, showing measurement windows. (Scott and Maxwell, 1989)

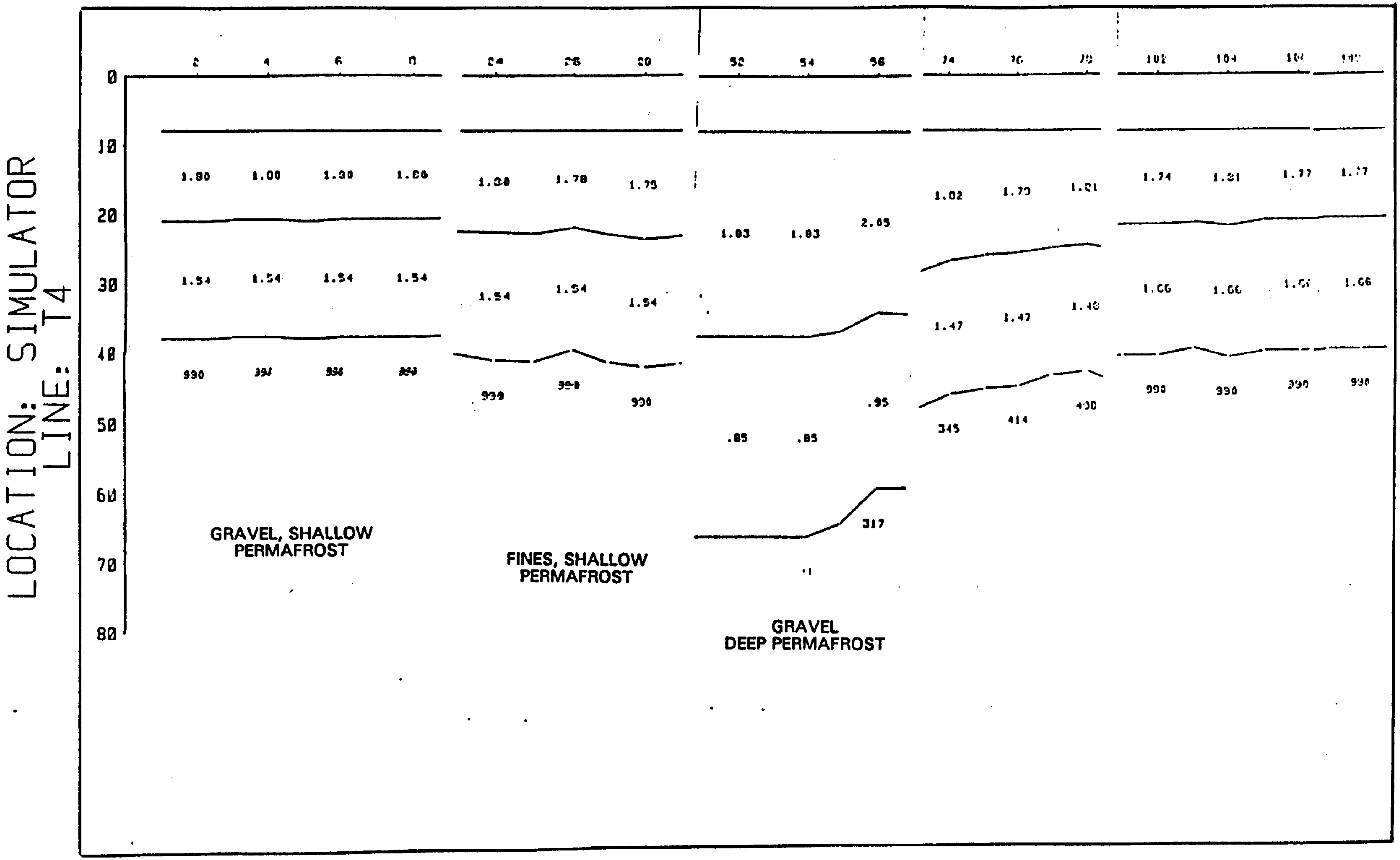

Figure 4: Parts of real-time inversion results from simulator run.

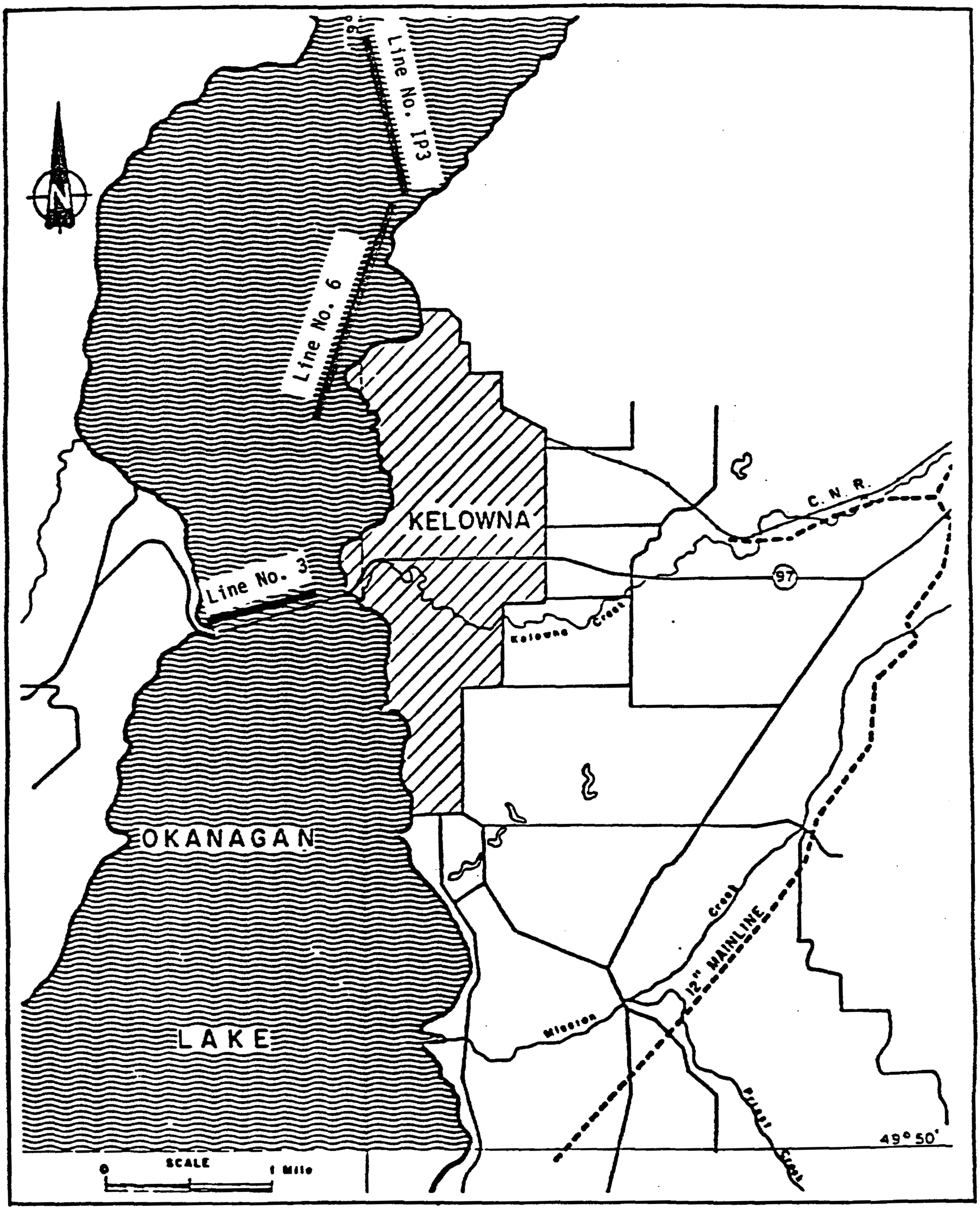

Figure 5: Okanagan Lake, showing survey lines for field trial.

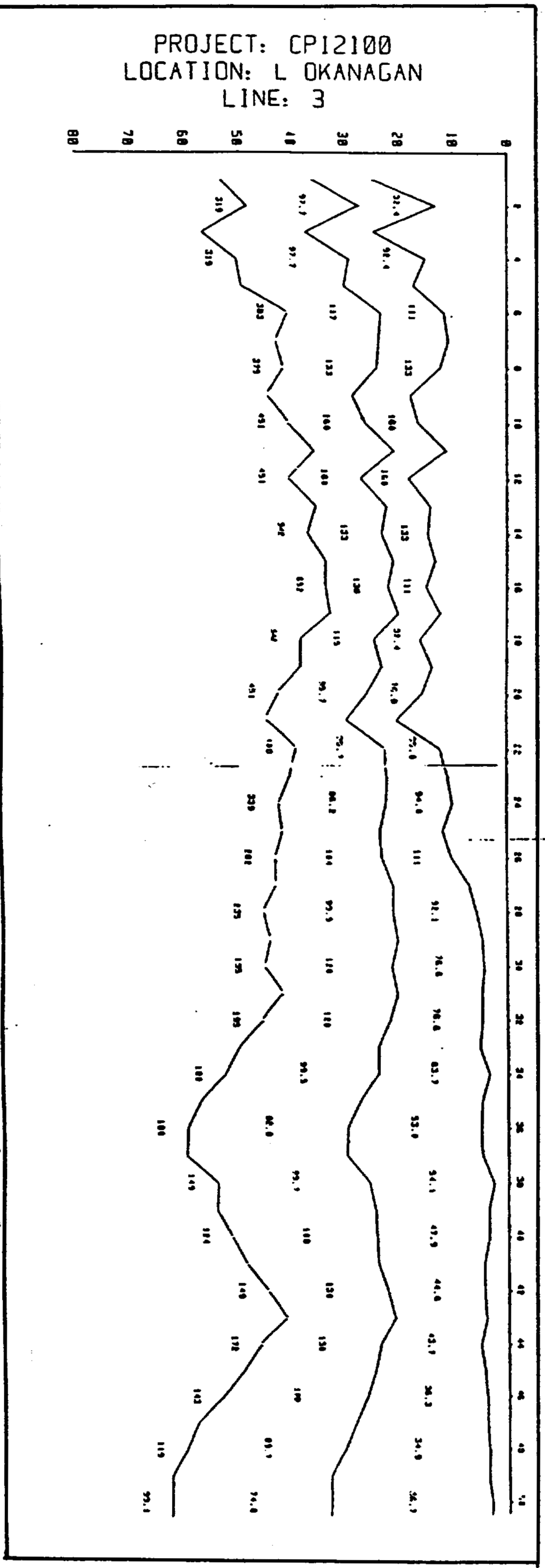

Figure 6: b) Part of Line 3 in Okanagan Lake, with result of real-time inversion of resistivity data.

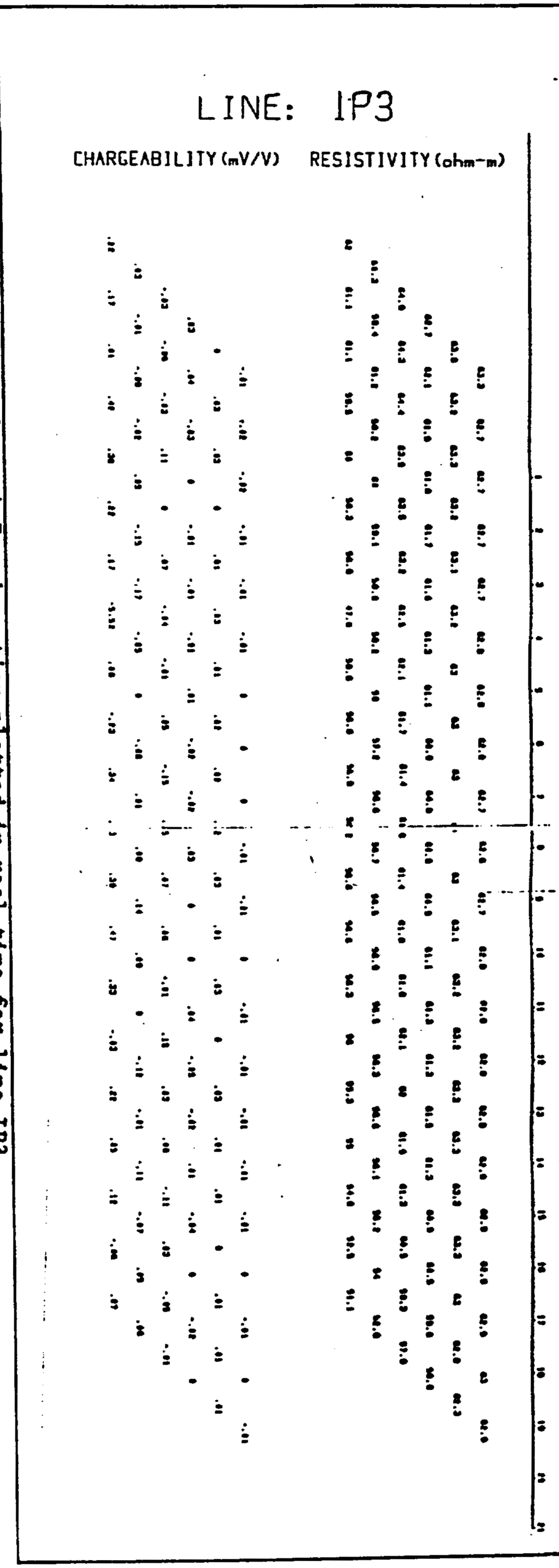

Figure 6: a) Pseudosection plotted in real time for line IP3.

PART 3

INVITED PRESENTATIONS

Canadian Hydrographic Service
Beaufort Sea Activities

Presented By George Eaton
Canadian Hydrographic Service
Institute of Ocean Sciences
Sidney, British Columbia

1.0 Background

Hydrographic efforts in the Beaufort Sea began in the 1950's when the U.S. ship "Storis" conducted surveys in support of the DEW Line Project. During the early 1960's, several CHS personnel accompanied both U.S. and Canadian Coast Guard icebreakers operating in the area. Soundings taken on the vessel's track were recorded at every opportunity, but this sort of data gathering falls far short of what is required to make a completed and accurate chart. Further endeavours included spot soundings taken through the ice during the winter and finally, some small rigorous surveys were undertaken from the 65 foot "Richardson" from 1962 to 1969. The Richardson remained in Tuktoyaktuk for most of these winters.

More extensive surveys were made in the 1970's with the four-launch ship "Parizeau". Each July, the ship made the passage from Victoria through the Bering Sea and fought the ice along Alaska's north slope to arrive in the Beaufort Sea survey areas near the first of August. Six or seven weeks of intensive work followed which the launches sounded 16 hours per day. Often the Atlantic Geoscience Centre would undertake a limited program at the end of the season before the Parizeau began her southern mid-September passage.

Hydrographic ships "Hudson" and "Baffin" have worked in the Beaufort, the most notable being the first survey of a portion of the shipping corridor in 1981. A number of other surveys were carried out from the chartered vessels "Pandora" and "Polar Circle" in the 1970's and 1980's and in many cases, there was a multi-disciplinary aspect to these projects. A contract was let in 1984 to a private survey company, Cansite Surveys, using the Banksland Surveyor for work along the Yukon coast from the 141st meridian to Herschel Island. the new government ship "Tully" has spent three seasons in the Beaufort since 1985.

2.0 Survey Characteristics

All of these surveys presented some problems for the CHS. The cost of operating in the Beaufort is high. Ships based in Victoria spent a month or more in transit to and from the survey area and only a limited amount of useful data was gathered on these passages. Ice in the survey area was frequently encountered and on some days, the seas were too rough for launch sounding.

Positioning systems, including Decca, Minifix, Argo and Syledis, were expensive to deploy and recover and in the early years before satellite positioning, there were sizeable distortions in the geodetic framework. Positioning accuracy of some of these systems was always a source of worry.

A characteristic of most of this work is the limited detail resulting from the wide line spacing associated with 100,000 scale resource mapping. Not until the 1981 corridor survey did the line spacing decrease to 100 m. Most of the recent work has been completed with this density. The line spacing, while suitable for charting and reconnaissance, will likely not be sufficient for pipeline or artificial island construction.

Accurate tidal data throughout the Beaufort is difficult to come by. The rule used in the first surveys was to substract two feet from all the soundings since little was known about the datums. Later, a permanent gauge was installed in Tuk Harbour and tides were extrapolated into the survey area. More recently, temporary gauges were installed closer to the survey areas and this data was used for the reduction of soundings and comparisons to the Tuk gauge data.

Coastline data shown on most charts throughout the Beaufort Sea comes from the NTS series of maps. Most of these maps were compiled from 1950's aerial photography and the effects of wind, seas and ice have been responsible for substantial changes in the last 30 or 40 years. More up-to-date photography is now becoming available and contracts have been let to Stewart Weir; however, it will not be incorporated until new chart editions are published.

3.0 New Methods and Technology

The short period of operation, expense of deploying positioning systems and uncertainty of ice coverage, among other factors, led the Hydrographic Service to explore other cost effective methods of acquiring soundings.

In the early 1960's, some data was gathered with hovercraft. This platform worked well in shallow waters, but was limited by fuel consumption. Stern tow fish, similar to mine sweeping gear, were deployed in 1983 with the Polar Circle. These fish, fitted with transducers and a positioning beacon, permitted three profiles to be gathered at once. Unfortunately, the cables frayed prematurely and the system was not an entire success.

3.1 Larsen

A system, not used in the Beaufort but showing great promise in other parts of the arctic where the water is not muddied by the Mackenzie River, is the Larsen system. This hardware operated by Terra Surveys consists of an airborne laser which produces pulses in the blue-green and infrared spectrums. The blue-green light penetrates the water and is reflected off the bottom, while the infrared is reflected from the surface. Depths can be calculated from the time difference of the returning pulses. Soundings can be obtained to 50 m or more in ideal conditions. The laser, currently operating at 20 Hz, provides a swath of nine spot soundings 25 to 30 m apart. Photogrammetric work is often carried out from the same aircraft.

3.2 TIBS

Another system, being used in its first production survey in Pelly Bay this winter, is TIBS, an acronym for "Through the Ice Bathymeter System". This equipment was developed in part by Geotech Limited in Markham, Ontario from techniques used in the mining industry for locating ore bodies. The electromagnetic system measures the amplitude and phase shift of a secondary magnetic field induced by transmitting coils in the bottom sediment. Translating these measurements to soundings is not straightforward and much of the development effort has focused on this data processing aspect. The equipment, which includes a large bird slung from an A-Star helicopter, is flown over the ice at 60 knots and produces continuous profiles. Sounding accuracies decrease with depth; however, acoustic quality can usually be realized in depths up to 50 m. Water clarity, bottom reflectivity and cloud cover do not affect the system. Depths to 100 m can be measured but, as with the Larsen system, ground truthing and calibration are extremely important.

3.3 Dolphin

Dolphin (Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation) is a semi-submersible intended for bathymetric surveying in off-shore waters. It is unmanned and remote controlled, designed to operate in up to 4 m swells at speeds up to 15 knots. With a number of these vehicles abreast of a mother ship, a swath of dat can be gathered with multi-beam echo sounders. The hazards of people working in small boats is avoided as well.

These vehicles, designed and built by International Submarine Engineering in Port Moody, B.C., are controlled through a radio link to the mother ship. The quality of the acoustic data is first rate and since the transducers are mounted in a semi-submersible heave is less of a problem. Applications for this system include mine countermeasures and route surveys for cables and pipelines, as well as general bathymetry. A major hurdle with the Dolphin is a ship handling system that can be used for easy deployment and recovery. Recently, a Newfoundland company, Georesources, has been contracted to carry out further development.

3.4 Global Positioning System (GPS)

The Global Positioning System is having a profound effect on the entire Hydrographic Service. Virtually every platform used to acquire data can now be positioned to better than 5 m in real time using differential techniques. The high costs of deploying radio positioning are avoided and the flexibility of choosing ice free survey areas is extremely attractive. Receivers are being purchased currently and work is now underway building radio links for the application of differential corrections.

The CHS has been following the progress of GPS over the last ten years. A number of contracts have been let to Nortech Surveys Ltd. for R & D in hydrographic kinematic applications. One of the deliverables of this work was software known as Hydrostar, whose function it is to take any receiver's signals and compute positions. This generic software has become the tool to compare receiver performance, determine differential corrections and log raw data. Other software capabilities include real-time error estimates and heave compensation.

3.5 Swath Sounders

Surveying in the Beaufort Sea is complicated by the ice pack and shallow water. Traditional methods are slow and generally lead to less than 3% of the bottom being ensonified. To maximize the benefit of the multi-disciplinary approach, total bottom coverage is desirable since this allows profile data from oceanographic and geophysical measurements to be interpolated with the greatest degree of certainty. Security of navigation in hazardous areas is, of course, increased with complete bottom coverage. There have been no CHS swath sounding surveys in the Beaufort to date.

Four Simrad EM100 sounders have been purchased by the CHS and are all currently deployed on east coast vessels. These systems operate at 95 kHz, giving maximum slant ranges to 550 m. Fans of 32 beams can be stabilized for ship motions and the swath widths can be up to 1.7 times the depth.

One characteristic of all swath sounders is the large volume of data they can produce in comparatively short periods of time. Powerful computers are needed to process and store the data and although a number of production surveys have been completed with these instruments, data management and processing techniques are still under development.

4.0 Trends in the Hydrographic Service

Fisheries and Oceans, Pacific Region, lost one of their major vessels, the Parizeau, to the east coast. Consequently, ship time is scarce and the CHS surveys must compete for vessel usage with all the other marine science projects on this coast.

As a result of the Brander-Smith Inquiry, electronic charts have taken on a greater significance in the CHS. The vast majority of our data exists on paper and a large job lies ahead to get this data into digital form and build an infrastructure to deal with it. About 50% of the Beaufort surveys exist in digital form.

There is a general move into the digital domain throughout the CHS. The lack of equipment and software tailored to hydrographic needs has made this a long drawn out process. Almost all survey data is now acquired and processed digitally and charts are directly constructed from these files with Universal Systems CARIS software.

5.0 Outlook for CHS Beaufort Sea Involvement

The Hydrographic Service's first priority is to provide adequate charting for safe navigation throughout Canadian waters. A substantial survey effort was made in the Beaufort Sea in the 1970's and 1980's when there was a distinct possibility that world oil prices would push the Beaufort resources into production and large oil tankers of the famed "Manhatten"'s size would be plying these waters. Since that time, there has been a reduction in Beaufort activity and the CHS has shifted their focus to other portions of the southern Northwest Passage.

The most recent work is a Larsen survey of Dolphin and Union Strait and small surveys conducted in conjunction with the Coast Guard for a suggested barge landing site in the Hamlet of Coppermine and site plan for Echo Bay Mines. These last surveys were funded by the clients.

Surveys of Victoria and James Ross Strait have a high priority for the future.

Geological Constraints to Off-Shore Granular Resource Assessment in the Canadian Beaufort Sea

Presented By Steve Blasco
Geological Survey of Canada
Atlantic GeoSciences Centre
Dartmouth, Nova Scotia

Knowledge of the Late Quaternary geological history and depositional environments of unconsolidated sediments composing the Beaufort continental shelf provides the technical basis for guiding the search for granular resources, determining the origin of deposits and constraining inventory assessments.

Regional seabed geological mapping of the Beaufort shelf has resulted in the subdivision of the shelf into nine physiographic regions (Figure 1, O'Connor, 1982). The surficial geology is continuous within eachof th enine regions, but varies considerably among regions. This mapping lead to the further identification of five prospective areas with high potentials for sand and gravel deposits (Figure 1). As this figure illustrates, all source areas located and used to date by industry are found within four of the five identified areas.

Granular resource exploration and development has been focused on the high potential areas of the central shelf north of Richards Island and the Tuktoyaktuk Peninsula (Akpak Plateau and Tingmiark Plain). To the west, the Herschel sill and western Yukon shelf (Natsek Plain) represent potential sand and gravel source areas. The balance of the Beaufort shelf is dominated by extensive areas of exposed fine grained sediments on and underlying the sea floor. Figure 2 (Blasco et al, 1990) is a schematic east-west cross-section of the shelf showing the distribution of sands and clays in the near surface sediments. Lack of success in locating gravel deposits during early exploration phases on the shelf lead to the expansion of the search to the coast line of southwestern Banks Island.

The recent history of the shallow sediments of the Beaufort and Banks continental shelves is dominated by the effects of the last sea level rise, an event which has continued over the last 10,000 years (Hill et al, 1985). This transgression has resulted in the erosion, reworking, concentration and deposition of most of the sand and gravel bodies developed to date. However, the depositional setting varies among borrow sites. Geological models accounting for the origin of these deposits have evolved and changed over the last decade. Seven models have been used to constrain exploration and inventory evaluations of granular prospects. Each of these models is discussed below with appropriate examples.

Model 1A (Figure 3) represents the current view of central shelf stratigraphy (Blasco et al, 1990). Unit C sands represent a broad caostal outwash plain deposited during the retreat of the late Wisconsinan ice sheet. The exposed surface of this sand plain was reworked by rising sea level. Fine sediments were removed and coarse-grained sediments were concentrated as lag veneers, barrier islands, beaches or channel bar deposits. With continued rise in sea level, these deposits were covered with high energy near shore interbedded sands, silts and clays of Unit B. As water depths increased off shore, these Unit B interbedded sediments were, in turn, succeeded by Unit A marine clays. Units C, B and A strata were deposited as a succession over the last 20,000 years.

The Unit B/C contact represents a major regional unconformity and source of reworked sand and gravel. Borrow deposits are found on the seabed of the Akpak Plateau and Tingmiark Plain where Unit B and Unit A sediments are not present or form only a thin discontinuous overlying veneer. In addition to these reworked Unit B/C unconformity deposits, exposed Unit C sands have been dredged extensively as artificial island construction material. Model 1B, in-situ sand deposits, is illustrated as Figure 4. The southeast Isserk and centrak Erksak borrow sites are examples of Model 1A and 1B deposits, respectively (Meagher and Lewis, 1988a and 1988b).

Dredging of Unit C sands at depth is frequently limited or retarded by the presence of shallow permafrost. Well-bonded ice-bearing sands form an effective barrier to the dredging process. In other areas such as south of the Isserk site, ice-bearing Unit C sands have thawed under the influence of warm Mackenzie River waters. Thawed Unit C sands have consolidated and the resulting depression has infilled with thick Unit B deposits. This process, which may result in substantial overburden thicknesses, may preclude access to Unit C sands as a resource.

The surficial on-shore stratigraphy of Richards Island consists of basal sands of the Kidluit and Kittigazuit Formations overlain by Toker Point morraine. Rampton (1988) regards this sediment sequence to be early Wisconsinan or earlier in age (65,000 year minimum date). When the first off-shore stratigrpahic model was proposed on 1980 (O'Connor, 1980), stratigraphic continuity with the on-shore was assumed and Unit C sands were considered correlative with the Kidluit/Kittigazuit Formations. The overlying Toker Point morraine existed in the off-shore and was eroded and reworked during the last transgression, resulting in the deposition of coarse-grained lag deposits off shore. These lag deposits formed the basal part of Unit B. Unit B interbedded sands, silts and clays and Unit A clays were subsequently deposited and are mostly Holocene in age, as noted in Model 1a and 1b above.

Model 2 (Figure 5) illustrates this original model. The implication was that significant thin deposits of reworked Toker Point morraine existed as granular sources in the coastal zone north of Richards Island, at least as far off shore as Rampton's proposed ice limit. Fortin (1989) used this hypothesis in his granular assessment of this area.

The on-shore/off-shore stratigraphic correlation is not supported by chronologic evidence. Unit C appears to be younger than 21,000 (Blasco et al, 1990) and little evidence of the Toker Point has been documented in the off-shore.

To date, the geological mistie between the on-shore and off-shore remains unsolved. A compromise model which possibly accommodates the observed stratigraphy extneds the Richards Island sequence into the near shore zone (Model 2). This sequence ultimately dips beneath the more recent off-shore sequence (Models 1a and 1b). This Model 3 is illustrated in Figure 6 and sugests that inliers and outliers of the older and younger sequences may exist in the off-shore. However, recent work by Lewis (1991) suggests lateral continuity of Unit C and underlying strata from the off-shore to the near shore zone.

Sand and gravel deposits may also be found in Unit B transgressive sediments. As sea level rises, eroding and reworking the coast line in its path, sediments are exposed to high energy wave and current regimes. Coarse-grained coastal deposits are reworked and concentrated to form beaches and barrier islands. Model 4 (Figure 7) illustrates this stratigraphy. Shallow seismic and borehole evidence reveals the Unit B/C unconformity at depth and a Unit B of greater thickness. The Issigak borrow site on the southern Kringalik Plateau is this type of deposit (MacLeod, 1987) and forms an anomaly within the region dominated by fine-grained sediments, both on the seabed and with depth. Issigak is probably a barrier island generated during the last transgression, less than 3,000 years ago (sediments directly underlying the gravels have been dated at this age). Areas of morphologic relief during sea level rise may be exposed to high energy regimes for prolonged periods of time, leading to the reworking and concentration of granular sediments.

Little evidence exists on the Beaufort shelf of glacial ice action. Well defined tills and/or moraines have not been recognized to date, with the exception of the Herschel sill area. An early (possibly late) Wisconsinan ice tongue advancing northward down the axist of the Mackenzie Trough (Blasco et al, 1989), deposited a lateral moraine along the eastern ede of Herschel Basin. This morraine forms a ridge or sill from Kay Point on the mainland, north to Herschel Island. Fluctuating sea levels have eroded and reworked the crest of the Herschel sill, resulting in the concentration of coarse gravels on the seabed (O'Connor and King, 1985 and Gowan, 1984). The moraine origin for granular deposits is illustred in Model 5 (Figure 8).

The origin of granular resource deposits on the western Yukon shelf (Natsek Plain) is complex and poorly understood. In the near shore zone, coarse-grained alluvial fans, deposited at the mouths of northward draining river systems during low stands of sea level, form shallow water sources of sand and gravel (Meagher, 1986). Off-shore, progressing northward across the shelf, successively younger Neogene to Quaternary strata outcrop on the seabed (Lewis and Meagher, 1991 and Blasco et al, 1990). On the outer shelf, seabed sediments have been dated at 53,000 years BP or greater. This implies that surficial shelf sediments may have been exposed to at least two cycles of sea level lowering, sub-aerial exposure, erosion and reworking during sea level rise. Coarse-grained glacial, fluvial and transgression related sediments have been remobilized, reworked and concentrated as sand and gravel deposits which form thin discontinuous patches on a much older substrate. This geologic Model 6 used to account for the origin of western shelf granular deposits is illustrated in Figure 9.

Little data exist to clearly define the origin or extent of granular resources in the near shore and immediate off-shore of southwestern Banks Island. Mode 7)Figure 10) illustrates a schematic cross-section of the coastal zone. Underlying alluvial and glacial till deposits have been eroded, reworked and concentrated by wave and current action during a rising Holocene sea level. Thin coarse grained lag gravel deposits are exposed on the seabed in shallow waters. In the near off-shore, these deposits are covered with fine-grained sediments (Fortin, 1987).

Continued geological research is required to identify new granular sources and to more clearly define the origin and spatial extent of existing deposits. Significant quantities of sand appear to exist on the southern Akpak Plateau and Tingmiark Plain areas of the central shelf. However, few sand sources exist in close proximity to exploration and developments sites in the west central Beaufort area. Known gravel sources are limited in number and volume. Regional dna site specific geological studies are required to find strategically located sand deposits and to significantly expand on the supply of gravel. More specifically, the near shore stratigraphy of the Richards Island area needs to be resolved to define the appropriate geologic model and to clearly define the granular resource potential of this area

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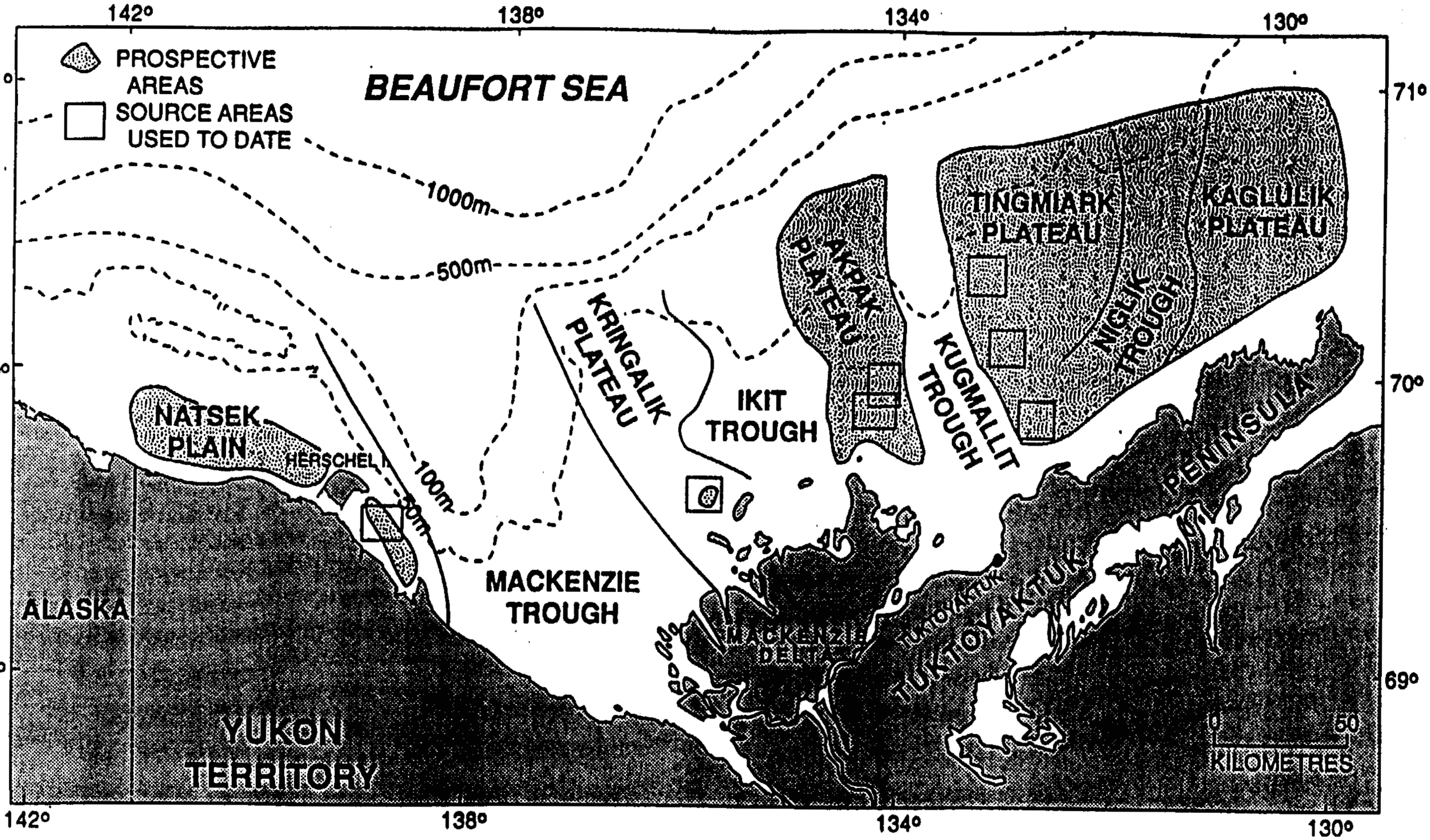
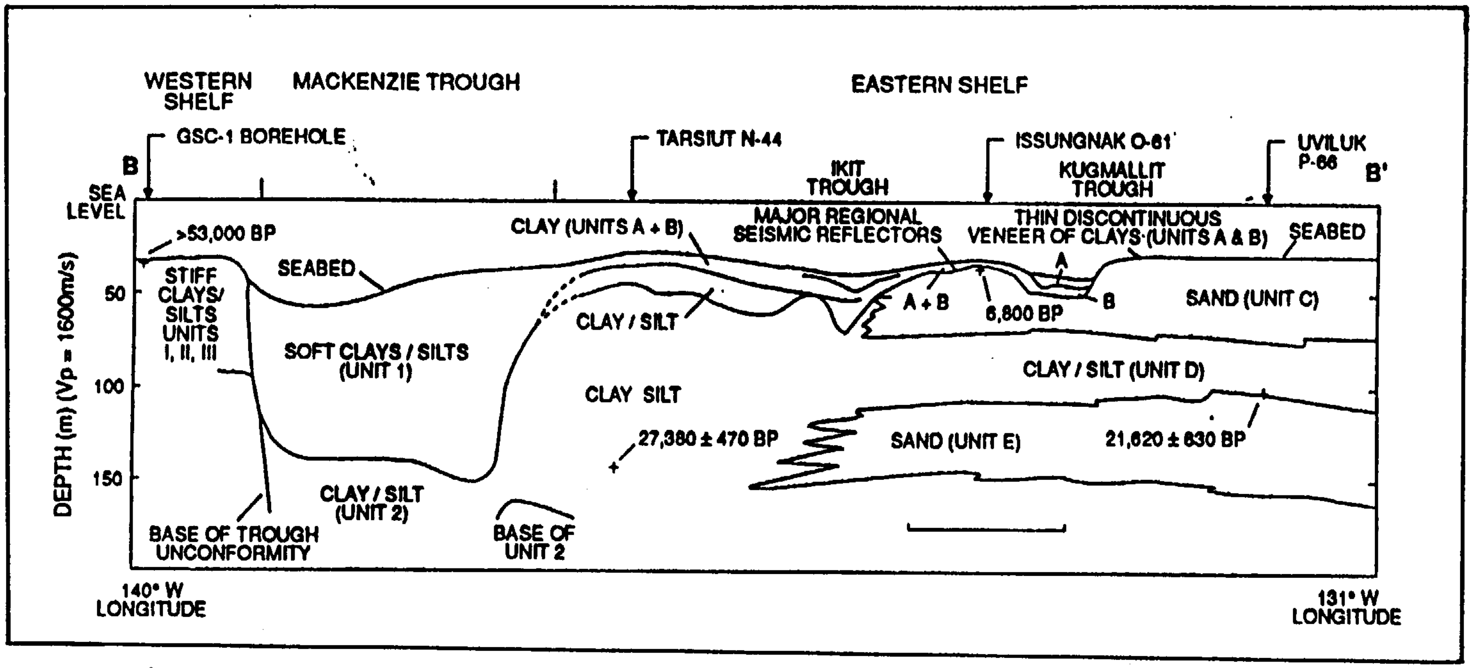


AREAS WITH POTENTIAL SAND AND GRAVEL RESERVES

FIGURE 1

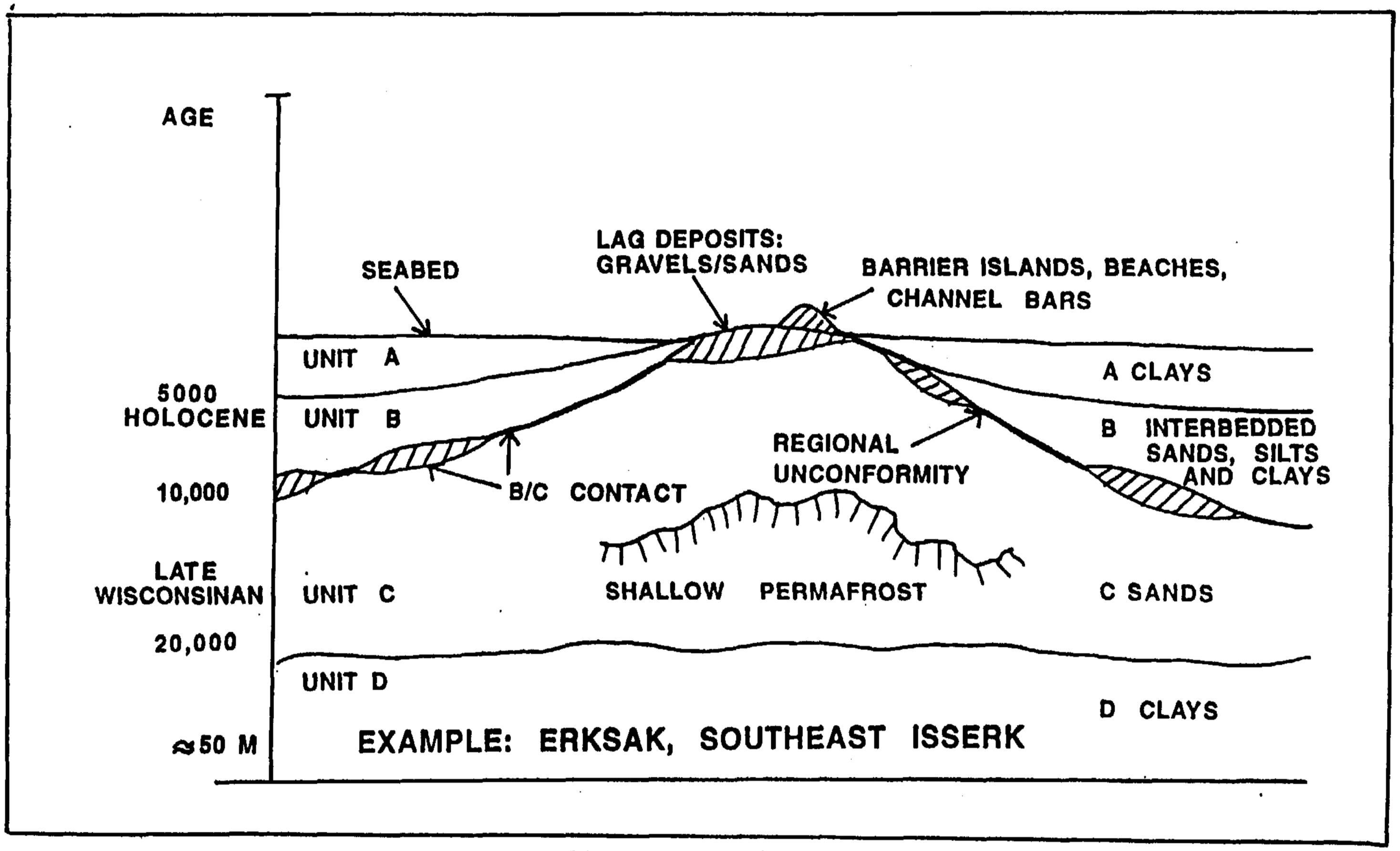
024/246/92/1/2



NEAR SURFACE CLAY AND SAND DEPOSITS

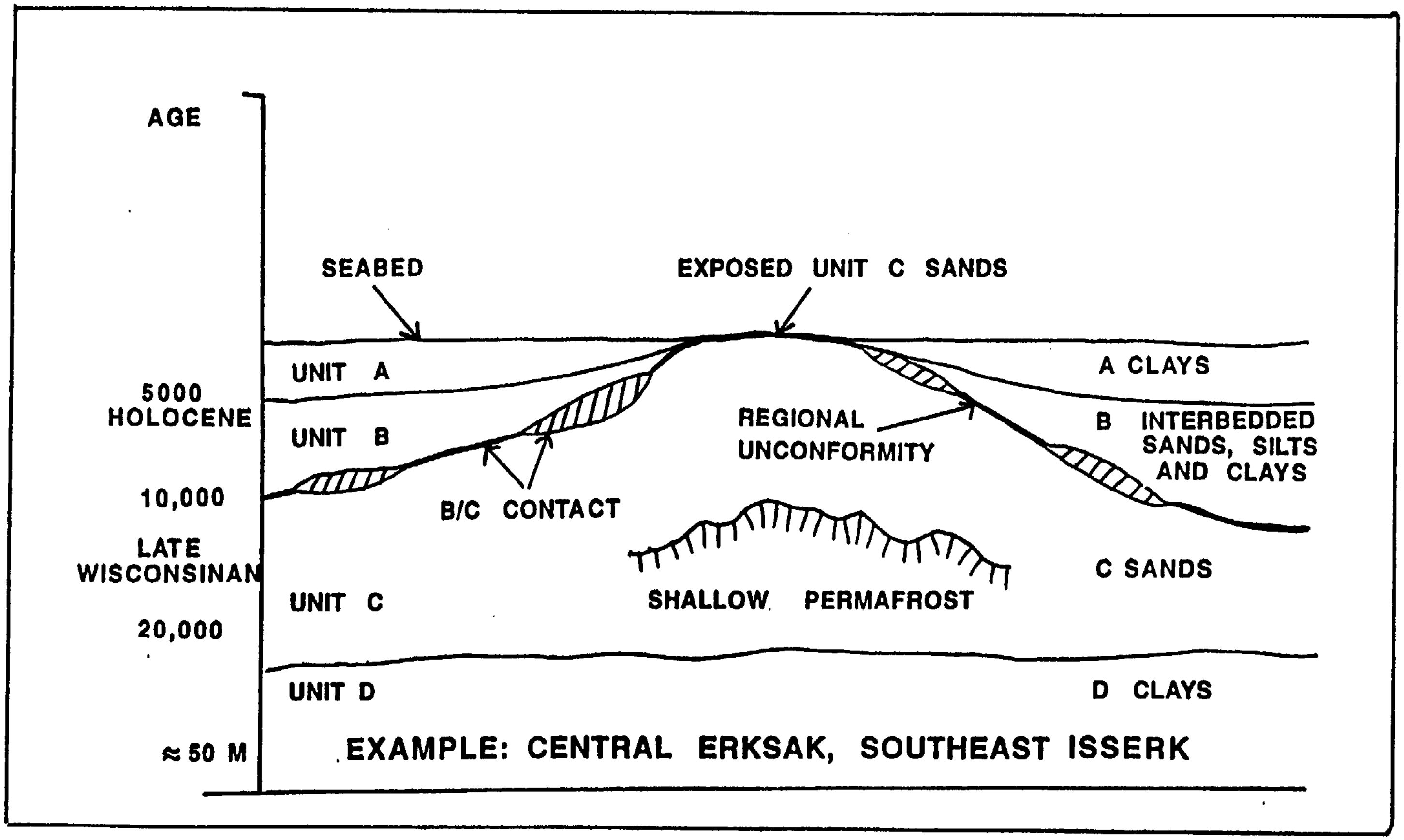
FIGURE 2

024/246/92/1/1



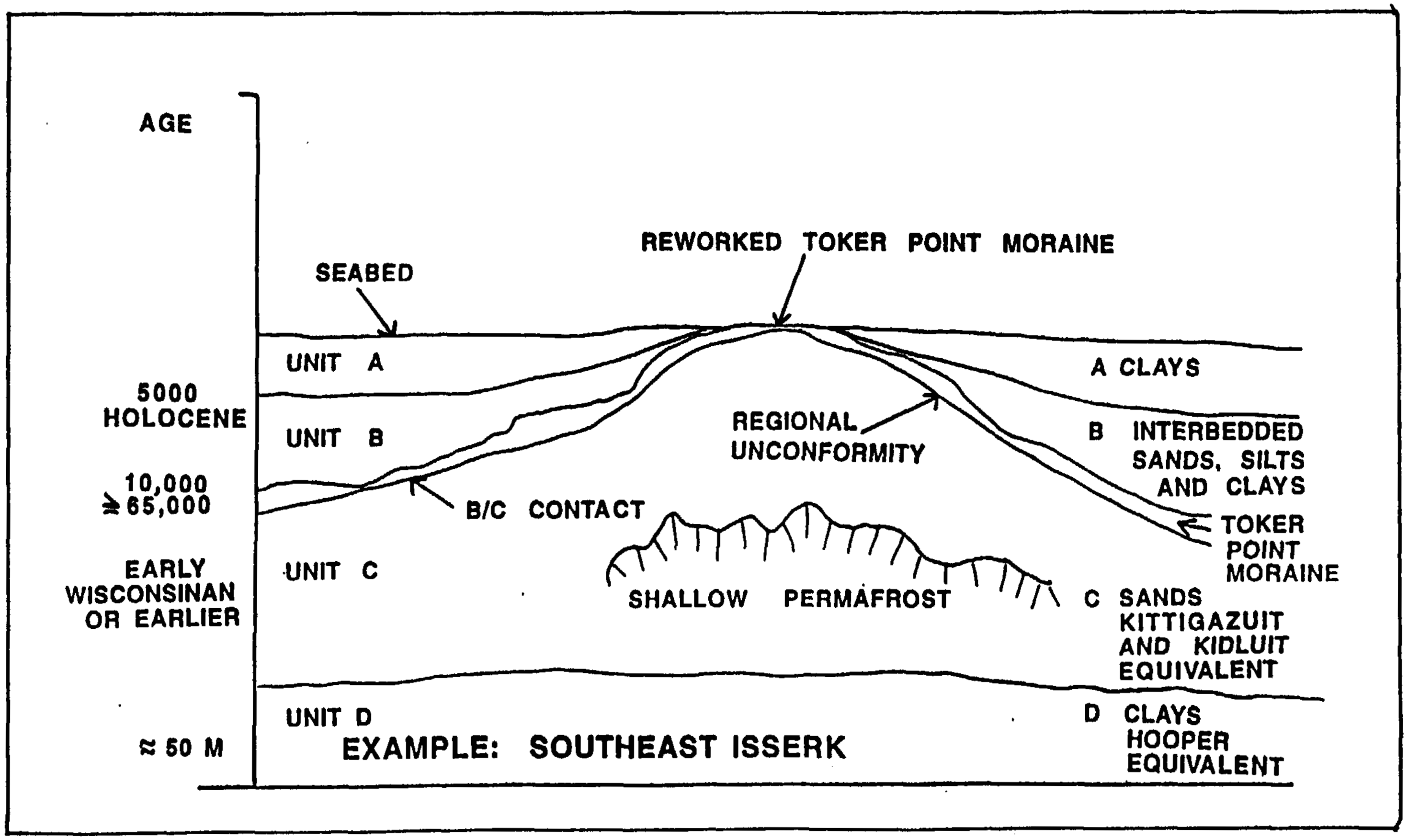
MODEL 1 a: RECENT REWORKED DEPOSITS

FIGURE 3



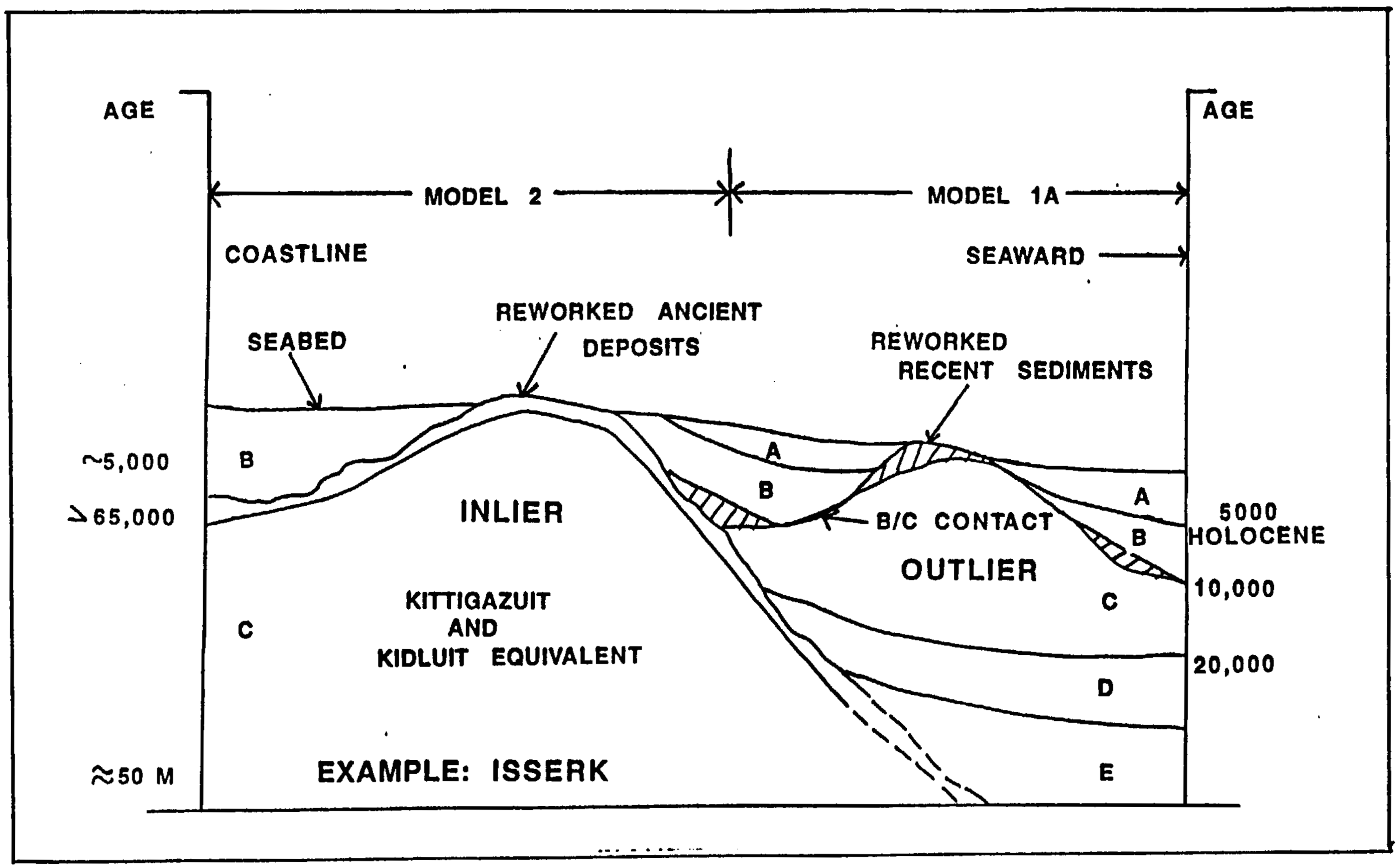
MODEL 1 b: RECENT IN - SITU DEPOSITS

FIGURE 4



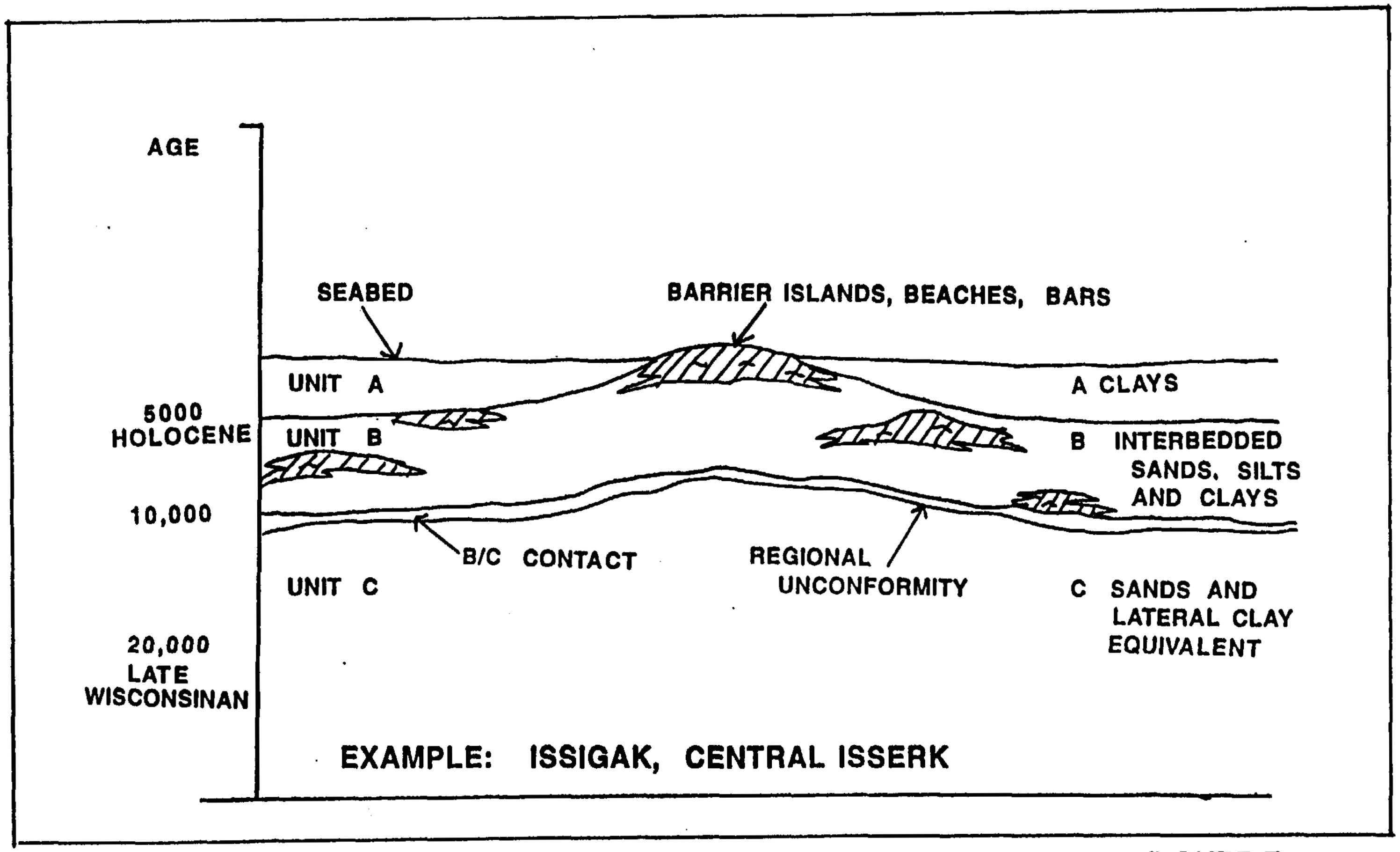
MODLE 2: ANCIENT REWORKED DEPOSITS

FIGURE 5



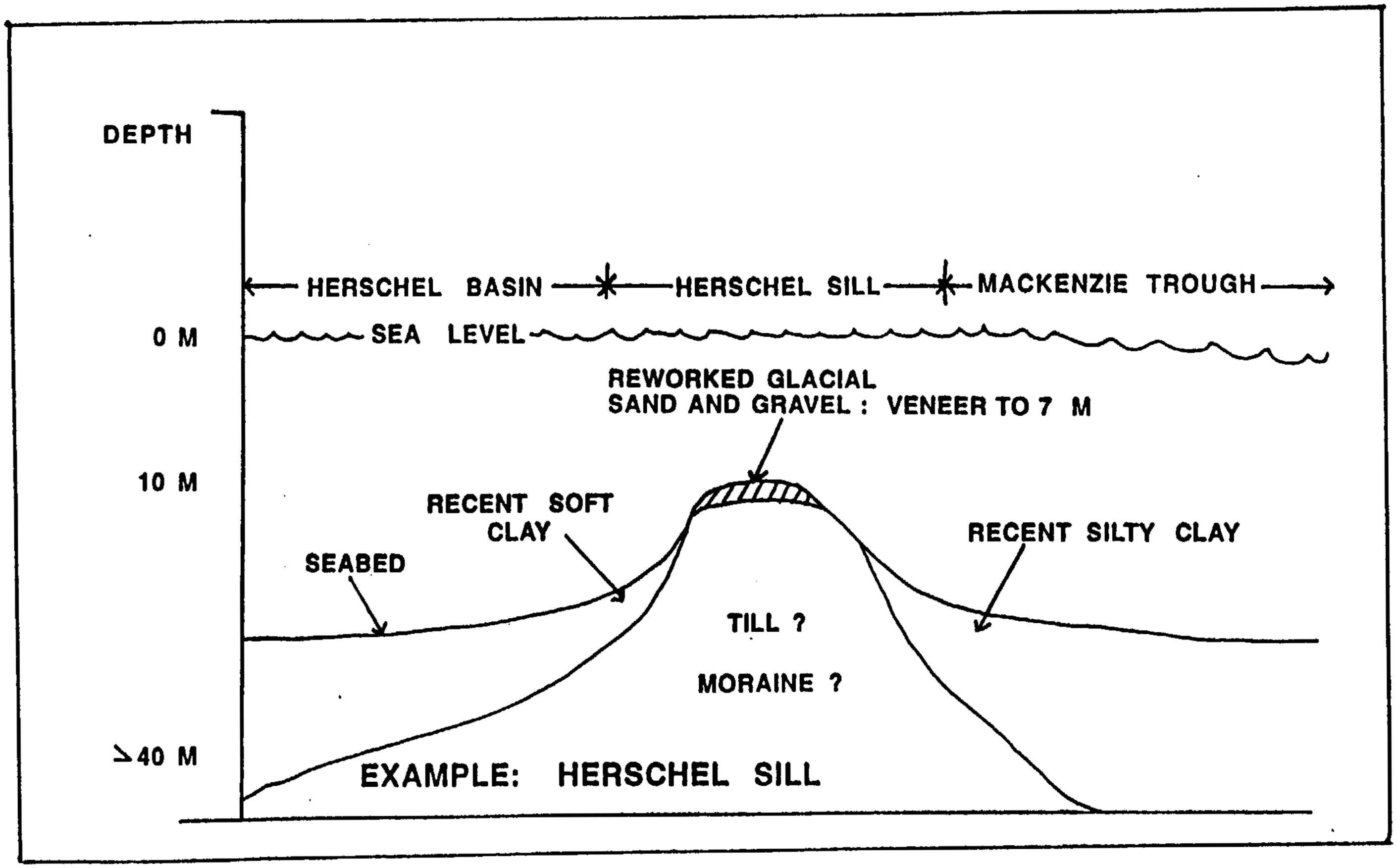
MODEL 3: INLIER / OUTLIER DEPOSITS

FIGURE 6



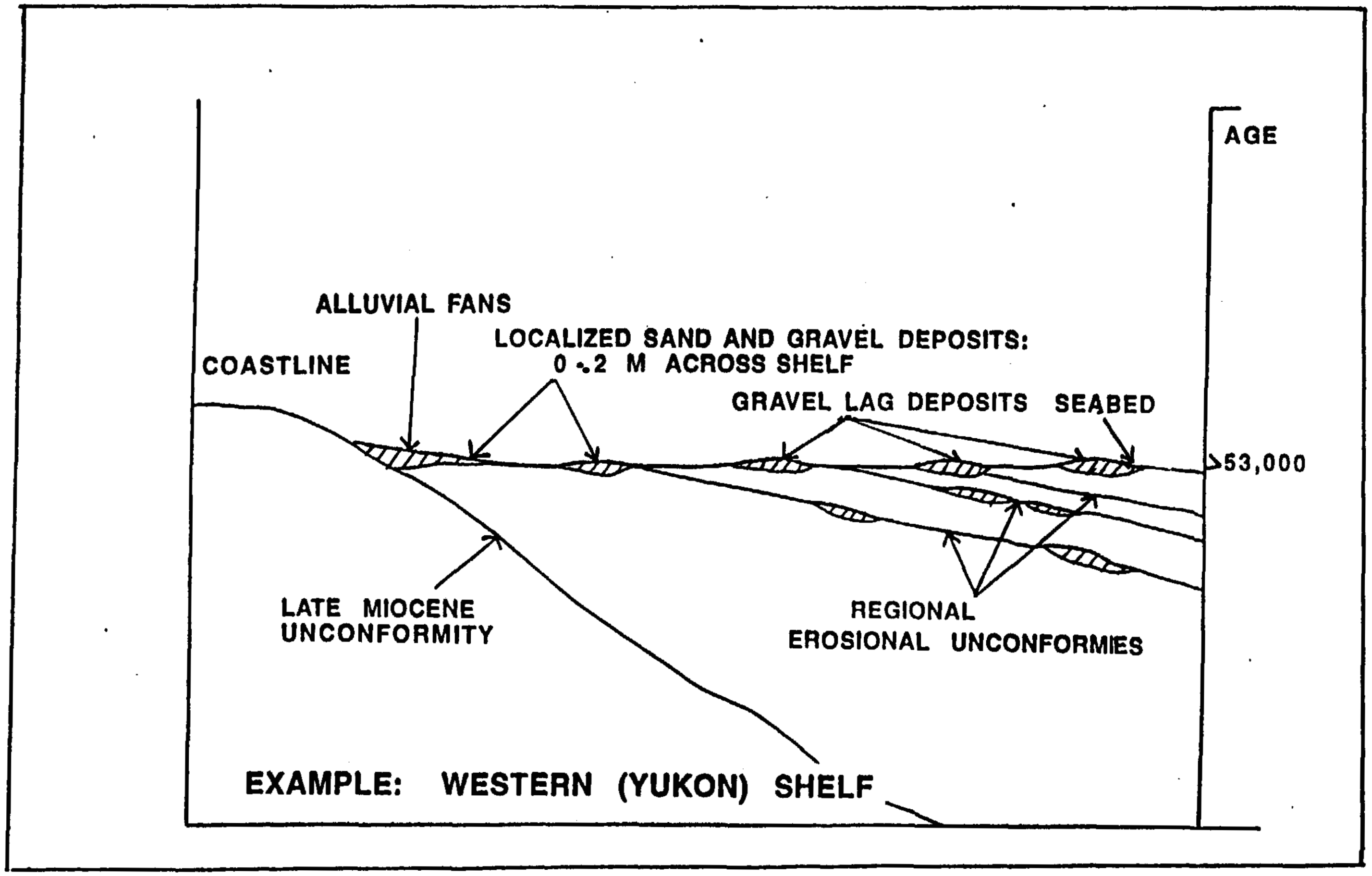
MODEL 4: TRANSGRESSIVE DEPOSITS

FIGURE 7



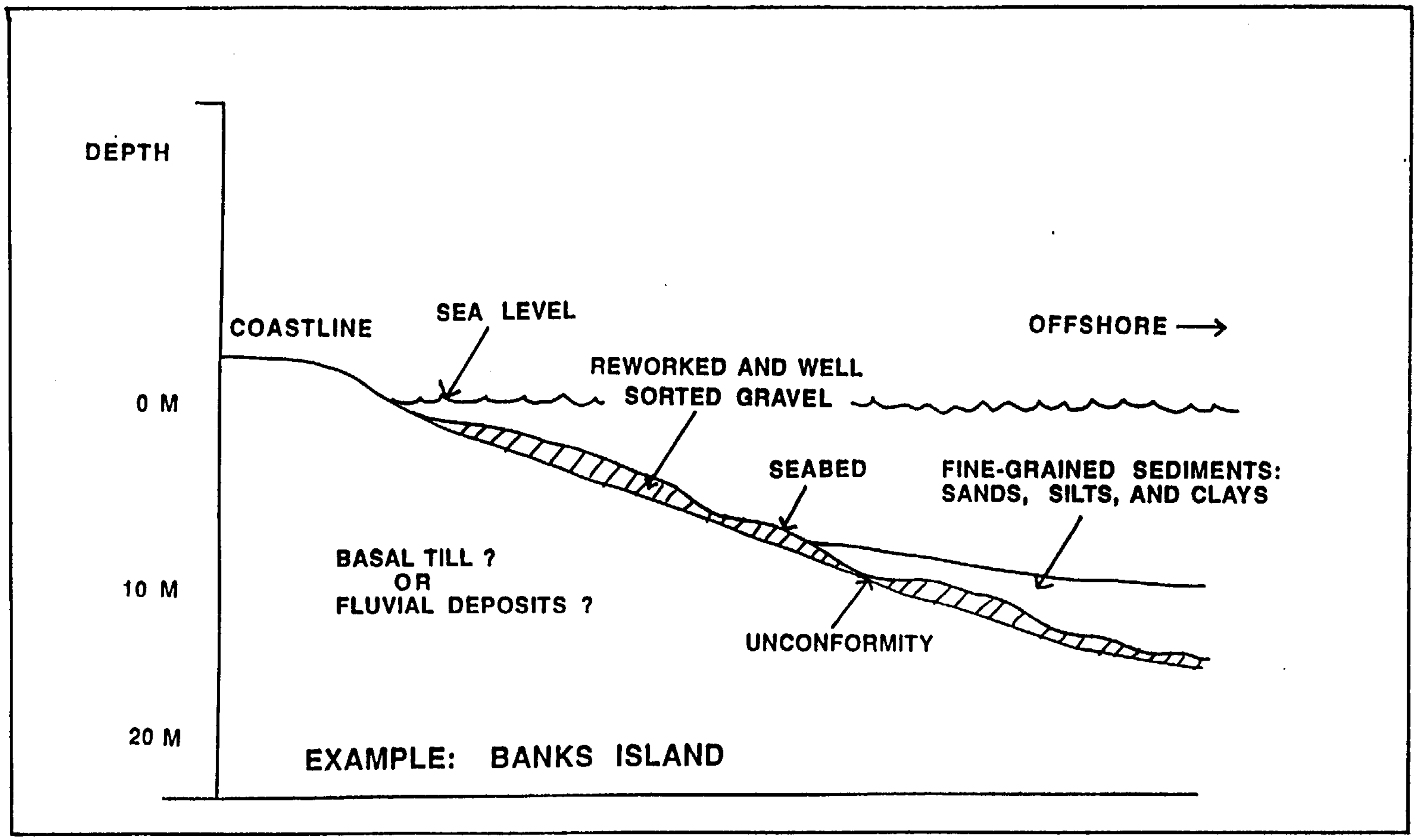
MODEL 5: REWORKED GLACIAL DEPOSITS

FIGURE 8



MODEL 6: UNDIFFERENTIATED MULTIPLE REWORKED DEPOSITS

FIGURE 9



MODEL 7: ALLUVIAL / COLLUVIAL COASTAL DEPOSITS

FIGURE 10

Arctic Off-Shore Exploration Structures
A Geotechnical Perspective

Presented By Kevin Hewitt
Canadian Marine Drilling Ltd.
Calgary, Alberta

1.0 Introduction

Since 1969, 142 exploratory wells have been successfully drilled in the Beaufort Sea (Masterson, et al; 1991). Of this total, approximately 100 wells have been drilled from a variety of islands and bottom-founded structures in water depths up to 32 m (Figure 1). The remaining wells have been advanced from floating structures in water depths up to 67 m.

The marine environment in the Arctic is characterized by sea ice cover for approximately 9 months of the year. The design of bottom-founded structures, from which drilling is performed during the winter months, is dominated by the requirement to resist forces imposed by this ice. This requirement becomes more critical in the "shear" zone, which is the transition zone between the land fast ice zone and the polar ice pack (i.e., beyond approximately 20 m water depth).

The variety of bottom-founded structures utilized has ranged from sandbag retained islands through to fully mobile bottom-founded structures. The diversity includes sacrificial beach islands, ice islands, gravel islands, caisson-retained islands and caisson/berm structures. The design and operation of these structures has been largely governed by geotechnical considerations. This paper reviews the evolution of the structures from this perspective. Based on this review, the paper concludes with an overview of past and present concepts for production structures.

2.0 Surficial Geology of the Beaufort Sea

The exploration area relevant to this paper includes both the Canadian and US portions of the Beaufort Sea continental shelf. The surficial geology east of Herschel Island (i.e., Canada) is more complex than to the west due to the dominance of the Mackenzie Delta. A geologic model has been developed for this area (O'Connor & Associates, 1980) which divides the shelf into nine physiographic regions, based on the combination of seafloor bathymetry, sediment types and the paleotopography of the most recent unconformity. The nine regions consist of five plains (or plateaus) separated by four troughs (or channels).

The troughs (channels) are generally characterized by fine-grained weaker soils. The plains (plateaus) in some instances contain relic sand ridges which have been the primary source of borrow material for island construction in the Canadian Beaufort Sea.

The continental shelf of the Alaskan Beaufort Sea is a seaward extension of the Arctic Coastal Plain. Sediments of the shelf consist of clay, silt, sand and gravel with the major constituent being silt and clay. Sand and gravel are more common in the near shore and shallow water off-shore. Sources of sand and gravel may appear as shoals, sand ridges, lag deposits and as seafloor sediments. The soils in the Alaskan Beaufort Sea are generally competent, although weak soils with shear strengths less than 50 kPa are present in some areas. These weak soils are generally limited to a thin surficial veneer typically less than a metre thick, or a buried layer less than a few metres thick.

The seafloor is considered flat on a regional basis. However the micro- topography is characterized by sharp relief as a result of ice ridge gouging. Elevations may vary locally over a range of 0.6 m to 2.4 m or more, particularly in water depths of 15 m to 25 m. This ice gouging has remoulded the uppermost soils and reduced their strengths.

3.0 Structure Types

Apart from the truly mobile units (i.e., those requiring no on-site construction), almost every "structure" has had its unique aspects. However, they can be divided into general categories and the seven listed below have been chosen to broadly classify the structures utilized to date (see Tables 1 and 2).

- Sandbag Retained Islands - 14 wells (13 "structures"). Maximum water depth of 7.0 m.

- Sacrificial Beach Islands - 12 wells (11 "structures"). Maximum water depth of 18.6 m.

- Ice Islands - 5 wells. Maximum water depth of 7.6 m.

- Gravel Islands - 46 wells (30 "structures"). Maximum water depth of 14.6 m.

- Caisson Retained Islands - 14 wells (8 locations). Maximum water depth of 32 m.

- Water Ballasted Caisson on Berm - 2 wells. Maximum water depth of 31 m.

- Mobile Bottom-Founded Structures - 7 wells (6 locations). Maximum water depth to date of 21 m.

Each of these structures is described below, with emphasis on the geotechnical aspects.

3.1 Sandbag Retained Islands

A sandbag retained island is one where a ring dyke of sandbags is placed on the seafloor to retain the fill. The purpose of the sandbags is to retain marginal fill materials and hence, achieve steeper islands slopes and to protect against wave attack. The geotechnical design considerations include slope failure, edge failure (a local passive failure due to the ice load), truncation failure (decapitation) and bottom sliding. Fill quality has not been a major design issue. The criterion has been to utilize fill of sufficient quality to support the drilling package. Borrow sources have included clam shelled local seabed materials and soils barged to the site from a remote submarine borrow pit. An example of the design of a sandbag retained island is provided by Riley (1975).

3.2 Sacrificial Beach Islands

Sacrificial beach islands have flat beach slopes (1:15 to 1:25) which are intended to attenuate wave energy and provide an erosion buffer, thus protecting the island top from wave attack. This type of island is usually constructed when the island is located near a large borrow source, since a large amount of fill is required. The major advantage of a sacrificial beach island is the reduced requirements on slope protection which is both costly and difficult to construct. Barge hauling of fill from a distant source is usually prohibitive in terms of cost and construction time.

The construction method for a sacrificial beach island is simple. The island fill is dredged and place hydraulically using plain suction dredges and floating pipelines.

The geotechnical performance of these fills is difficult to quantify owing to a number of factors. First, the acceptance criteria for borrow material have been set only to ensure the dissipation of pore pressures built up during construction. The quality of the placed fill has not generally been verified. Second, no attempt is made to achieve steep slopes. Flat slopes are desirable to dissipate wave energy. A geotechnical "failure" of a locally steep slope during construction has not been considered a failure but, rather, a part of the construction process. Further, such a "failure" would be difficult to distinguish from slope flattening due to wave erosion. However, there are several observations which indicate that liquefaction "failures" have occurred. Third, because these islands have been situated in the land fast ice region and have generally been surrounded by large rubble fields, it is likely that they have not experienced significant horizontal shear loads.

The very flat side slopes has precluded the economical use of this approach at deeper water sites. Volume increases exponentially with water depth. Geotechnical considerations related to the construction of two sacrificial beach islands are outlined by Shinde, et al (1986).

3.3 Ice Islands

Spray ice islands have become a fairly routine option for prospects located in favourable water depths and ice regimes. The controlling issue is whether or not adequate drilling time can be provided following completion of island construction. The major advantage of such islands is the ready availability of the construction material and the subsequent natural decay.

Apart from the requirement for global sliding stability, a spray ice structure introduces unique considerations, as it is made of a material that is significantly weaker than the sea ice which surrounds it. The time-dependent behaviour becomes an important operational consideration. Island settlement during drilling, as well as lateral deformations associated with relatively low levels of load caused by pressure build-up and/or movement in the surrounding ice sheet, must be considered. The design and construction of the Mars Spray Ice Island is described by Funegard, et al (1987).

3.4 Gravel Islands (Armoured - Slope Islands)

The advantages of using good quality gravel for island construction is the reduced fill quantities resulting from steep slopes (1:3 to 1:5). These islands have been the most common type in the Alaskan Beaufort Sea where abundant sand is not available and non-U.S. dredges are not permitted to work. The gravel has been obtained from on-shore sources and either dumped on site by barges during the summer or, more commonly, hauled directly to the island site in winter via an ice road. The source of this gravel is described by Schlegel and Mahmood (1985). It is relatively abundant east of the Colville River to the Canadian border. These islands have been protected by a revetment, normally consisting of large sandbags overlying filter cloths, although other types of armour have been used. The disadvantage of this island type is that the placement of the slope protection can be very time consuming, especially below water.

The geotechnical design issues for this island type are similar to those for sandbag retained islands, although slope failure obviously becomes more critical. Consideration can also be given to strength gain at the seabed interface due to consolidation between the time of placement and the time of maximum anticipated ice load. Thaw settlement of loose frozen fill placed in the water, especially the underwater portion, has to be considered. The engineering and construction of Mukluk Island in 14.6 m of water is described by Ashford (1984).

3.5 Caisson and Caisson Retained Islands

The 1980's saw the introduction of a number of hybrid exploration islands designed primarily to reduce the fill volume requirements at deeper water locations. Four water line penetration systems were developed:

- Canmar's concrete caisson system, the "Tarsiut caissons" (1981) (Fitzpatrick and Stenning, 1983).
- Canmar's single steel drilling caisson, the "SSDC" (1982) (Fitzpatrick, 1983).
- Esso's segmented steel caisson, the "CRI" (1983) (de Jong and Bruce, 1978).
- Gulf Canada Resources Ltd.'s monolithic annular caisson the "Molikpaq" (1984) (Bruce and Harrington, 1982; McCreath et al, 1982).

Although the details of each system vary, deployment of all systems has commenced with the building of a steep-sided (1:6 - 1:8) sub-sea sand berm on which the caisson is placed. As most proposed sites did not possess suitable local borrow material, trailing suction hopper dredges were introduced to transport sand from remote locations. Trailing suction hopper dredges pick up material from a submarine borrow source by dragging an arm along the seabed. They are capable of carrying up to 8,000 m^3 of sand per load. Apart from the SSDC, which was ballasted onto the berm with water, all the systems required backfilling of a central core with sand.

The deployment of these new systems demanded a significant increase in design effort from that required for the previous more rudimentary structures. The basic design issues are not appreciably different from those of any other major civil work. However, the unique environmental loads and the restrictions in construction season length, construction plant and borrow materials created some major challenges. The geotechnical components included site investigations, stability and deformation analyses, quality assurance programs and performance monitoring. The location of these structures, in the unstable "shear" zone, precluded the prior technique of conducting the investigations from the land fast ice surface in the spring using conventional terrestrial methods. Hence, marine supported operations were employed during the short open-water season. These operations also incorporated the routine use of insitu testing techniques, including the cone penetration test (CPT), vane shear tests and the self-boring pressure meter (Ruffell et al, 1985). The introduction of the trailing suction hopper dredges required the identification of acceptable sand deposits at or close to the surface. This was accomplished by conducting regional shallow seismic surveys in conjunction with extensive shallow boring programs. Beyond static stability issues, the requirement to place a heavy structure on a berm capable of resisting the large horizontal ice loads that were anticipated in the "shear" zone required that the issue of dynamic stability be addressed. The consequences of liquefaction failure of such islands are potentially catastrophic. The criterion first proposed was based on a pseudo-static approach which called for a gradational specification to inhibit pore pressure generation and a relative density which ensured dilative behaviour during shear. Use of the "steady state" method (Poulos, 1981) was subsequently successfully employed. There are, however, problems related to insitu determination of sand state (Sladen and Hewitt, 1989; Sladen, 1989).

In order to assess structure performance and, in particular, to develop "alert" criteria based on monitoring of instrumentation, it is necessary to make an accurate prediction of load deformation behaviour under ice loading. For these structures resting on sand berms, the non-linear elastic hyperbolic model of Duncan and Chang (1970) was adopted. Fill quality assurance and insitu density evaluation became a significant component of construction operations. This involved monitoring of material loaded into the dredges, post placement coring and CPT testing. This also implied that a material specific correlation between tip resistance and density had to be developed (Berzins and Hewitt, 1984).

A number of instruments were employed to assess the response of the structures and foundations to ice loads. The primary monitoring method utilized manual and in place inclinometer systems. Other instruments and methods included piezometers, total pressure cells, extensometers, tilt meters, settlement systems and conventional survey methods. The performance of these "caisson" structures has generally been acceptable (Blanchet, et al, 1991). Actual ice loadings have been well below design values and therefore the corresponding deformations have been small (Blanchet, et al, 1991).

3.6 Mobile Bottom-Founded Structures

The most recent generation of off-shore exploration structures developed for use in the Beaufort Sea have been mobile bottom-founded structures. Although similar in some respects to gravity base structures that have been used widely in non-Arctic oceans, they have some unique characteristics that have been dictated by the need to resist high horizontal ice loading. Two such units have been built and deployed, the Concrete Island Drilling System, 'CIDS', operated by Global Marine Ltd. (Masonheimer, et al, 1986) and the steel SSDC/MAT system operated by Canadian Marine Drilling Ltd. (Hewitt, et al, 1988). The latter was a development of the SSDC caisson that had previously been based on a hydraulic fill berm. For the new system, the berm was replaced by a specially fabricated steel base or mat which was mated to the SSDC.

These systems offer two major advantages over the earlier units. Firstly, they can operate in relatively deep water (up to 17 m for the CIDS and 25 m for the SSDC/MAT) without the need for an artificial berm or sand core. This avoids the cost of berm construction, the need for suitable berm material and the problems associated with decommissioning. In the Canadian Beaufort Sea, where sand had been the traditional construction material, the need to undertake costly densification to eliminate the risk of liquefaction was also avoided. The second advantage is that there is no need for site preparation.

The base design for these structures is governed by geotechnical considerations. The features of the surficial sediments in the Beaufort Sea have been described previously. Some typical shear strength profiles are illustrated in Figure 2. The structures develop high lateral load resistances in these conditions by means of their large bases which incorporate a grid of horizontal strip anchors. These 'skirts' project from the base and are forced into the seabed when the unit is ballasted down (Figure 3). As a result, they accommodate some unevenness in the seafloor and efficiently develop lateral resistance. The components of lateral resistance are passive resistance and base friction. The depth of penetration of the skirts is controlled by the soil strength in relation to the available ballast weight. For relatively stiff soils, the penetration is low and the majority of resistance is derived from the skirt tips. For soft soils, the skirts can penetrate until the base comes into contact with the soil. In such uses, the passive resistance is the major component.

As with caisson islands, geotechnical assessments of these structures must address not only the overall stability but also deformations under ice loading. Detailed predictions of foundation deformation have made use of non-linear finite element analysis (Sladen, et al, 1990). These are important, not only from the viewpoint of serviceability but also with respect to monitoring. As direct measurement of ice loads is impracticable, geotechnical instrumentation, predominantly in place inclinometers, has been the primary means of setting alert criteria. Foundation deformations can be related to ice load level and hence to margin of safety.

More recently, the use of geotechnical instrumentation in conjunction with detailed predictions of deformation, have been explored as a means of measuring ice loads from observed ice events and hence assisting in the rationalization of ice design criteria. Although estimated ice loads are approximate, results have been encouraging and the method is arguably as reliable as any other method of estimating ice load (Blanchet, et al, 1991).

Table 3 (from Blanchet, et al, 1991) shows the results of ice load estimations for six sites (four caisson locations and two SSDC/MAT locations). For comparison, the range of ice loads measured by other methods is also indicated. As can be seen, estimated ice loads have all been less than 200 MN. This is significantly lower than design loads that would have been predicted for the ice events, based on available data during the early stages of off-shore development in the Beaufort Sea. The accommodation of ice loads is one of the major engineering challenges that must be met if off-shore production facilities are to be developed in the Arctic. Detailed geotechnical modelling and instrumentation have provided valuable data that have shown that traditional design ice loads were very conservative. By providing a rational basis for lower design ice loads, one of the major potential barriers to development has been reduced.

4.0 Summary

Exploratory drilling for hydrocarbons has been conducted from off-shore "structures" in the Beaufort Sea for over twenty years. The initial "structures" consisted of a variety of earth fill islands in very shallow water depths. In the late 1970's, this concept, with variations and refinements, was extended into deeper waters. In the early 1980's, composite caisson/earth fill structures were introduced. The limited data base on ice at that time lead to high design ice loads with the result that massive structures were required. These large earth fill structures were, however, associated with problems such as liquefaction and decommissioning.

By the mid-1980's, with the accumulation of considerable design and operational experience, it became feasible to utilize fully mobile structures. These units develop lateral resistance by mobilizing the shear strength of relatively competent soils below the seabed surface. Today, exploratory drilling is efficiently conducted from such structures on a routine basis.

5.0 Production Structure Concepts

When the Beaufort Sea - Mackenzie Delta Region Environmental Impact Statement (EIS) was prepared in 1982, a number of possible production structure concepts were tabled. These are briefly described as follows.

5.1 Dredged Islands

Dredged islands were proposed as production platforms in shallow water (0 to 20 m). These were seen to be similar to sacrificial beach islands with slope protection to prevent erosion. They would also extend further above the surface to minimize run-up of waves during fall storms. Slope protection would be provided by rock and gravel or man-made materials.

5.2 Caisson-Berm Island (Caisson Retained Island)

The caisson-berm production platform would initially be constructed as an exploration platform. If hydrocarbon discoveries demonstrated sufficient reservoirs, production could be undertaken at the site by expanding the island.

5.3 Gravity Structures

A gravity structure was envisioned to be somewhat like some of those used in the North Sea. Relying on its own weight to anchor the platform in place, the caisson was seen to be constructed of concrete and would be about 90 m in diameter at the water level. The advantage of this structure was that it is relatively simple and could be totally fabricated in the south. The ability of the structure to resist the limit stress forces associated with an ice island interaction was the subject of on-going studies. A variation of this concept was to place the gravity structure on top of a dredged berm.

5.4 Monocone Structure

This proposed steel or concrete structure was a variation of the monopod structures used in Cook Inlet, Alaska. The structure would be anchored to the seafloor with piling or by its own weight. It was felt that this design could safely resist most of the ice forces which could be exerted upon it by ice features in the Beaufort Sea. However, its resistance to loads from a large ice island was questioned.

5.5 Arctic Production and Loading Atoll (APLA)

The island building technology developed at that time was seen to be applicable to building production islands even in deep water. The largest concept for off-shore platforms was called the Arctic Production and Loading Atoll (APLA). A number of alternate concepts were proposed. One concept consisted of two islands forming a protected harbour or lagoon. The islands were designed to withstand the forces associated with ice island impacts.

The APLA would be built from granular material, dredged from borrow sites as near as possible to the APLA site. The type of dredgers used would be dependent on the water depth of the APLA, the distance to the borrow site and the time allocated to build the APLA. If an APLA were eventually built at a site like Kopanoar (60 m water depth), approximately 100 million cubic metres of material could be required and a quantity of clay would first have to be removed from the site. This work would require specially designed dredges because of the water depth and the long haul from likely borrow sites. Locations in shallower water depths would require considerably less borrow material and in some cases, where bottom conditions permit, stationary suction dredges could be utilized. A site in 25 m of water would require approximately 30 million cubic metres of material.

Since the compilation of the EIS, three events have transpired. Firstly, significant research efforts applied to the understanding of the ice environment and ice mechanics has resulted in a better understanding of the environmental forces. It now appears feasible that the design global ice load could be set in the order of 100,000 tonnes. Ten years ago the massive structures envisioned were designed to resist loads ten times these values.

Secondly, the typical development scenario of a decade ago was a megaproject based on regional reserves in the order of 1 - 2 billion barrels of liquids. Discoveries to date total several million barrels which do not support the capital costs of APLA type structures. Lastly, operations and research has shown that steel plated structures can be designed and constructed with capital costs that show favourable economics based on discoveries to date. Today's concept for a production platform would consist of a water ballasted steel plated structure, potentially sitting directly on the seabed. Where foundation conditions are unfavourable, excavation of the weak soils and replacement with granular material would be required.

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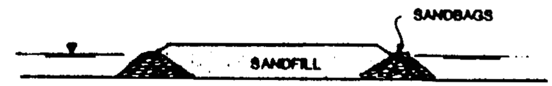
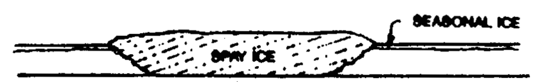
TYPE	MAX. WATER DEPTH	NUMBER OF LOCATIONS	DESCRIPTION	SCHEMATIC ILLUSTRATION
Sandbag Retained Islands	7	13	Ring dyke of sandbags retaining internal hydraulic fill E.g. Adgo F-28,Ellice L-39	
Sacrificial Beach Islands	19	11	Hydraulically placed sand fill with flat-side slopes E.g. Alerk P-33 ,Immerk B-48	
Ice Islands	8	5	Seasonal ice thickened by flooding or spraying until base in contact with seabed. E.g. Mars, Angasak	
Gravel Islands	15	30	Coarse fill placed usually by barge dumping or trucking on ice. Erosion protection usually provided E.g. Pullen E-17, North star	

TABLE 1 NON - CAISSON ISLANDS

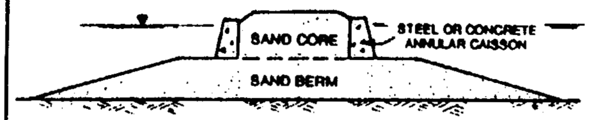
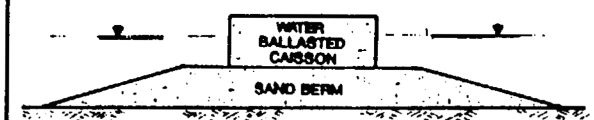
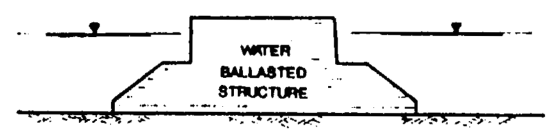
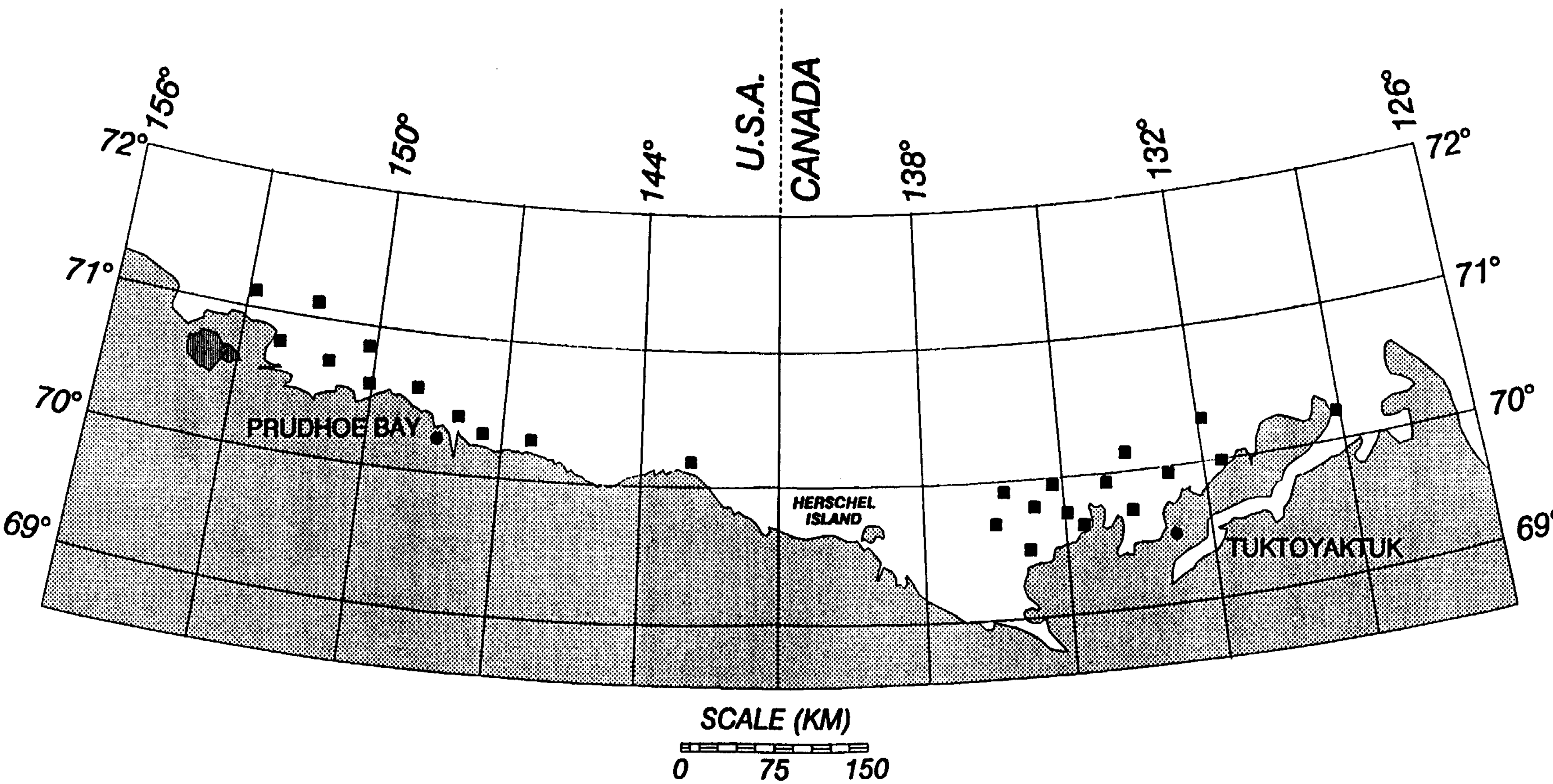
TYPE	MAX. WATER DEPTH	NUMBER OF LOCATIONS	DESCRIPTION	SCHEMATIC ILLUSTRATION
Caisson Retained Islands	21m + Berm Height	8	Similar to sandbag retained island but caisson used to retain fill allowing greater depth range E.g. Tarsiut Caissons, CRI, Molikpaq	
Water Ballasted Caisson/Berm	9m + Berm Height	2	Water ballasted caisson used in place of fill in wave and ice scour zone, placed on hydraulic sand berm. E.g.SSDC	
Bottom Founded Structures	25	6	Bottom founded structure , mobile and avoiding need for any fill berm E.g. CIDS, SSDC/MAT.	

TABLE 2 CAISSON ISLANDS

FIGURE 1

LOCATION OF OFFSHORE STRUCTURES BEAUFORT SEA



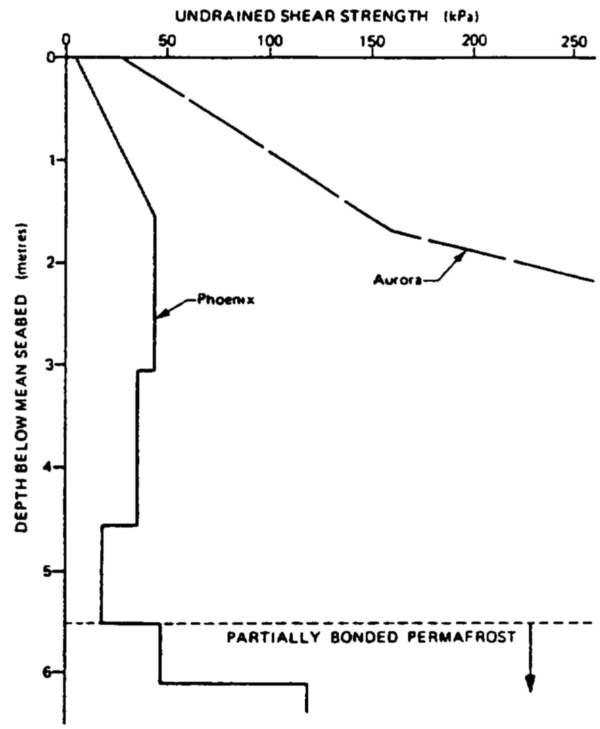


FIGURE 2

DESIGN UNDRAINED SHEAR STRENGTH PROFILES

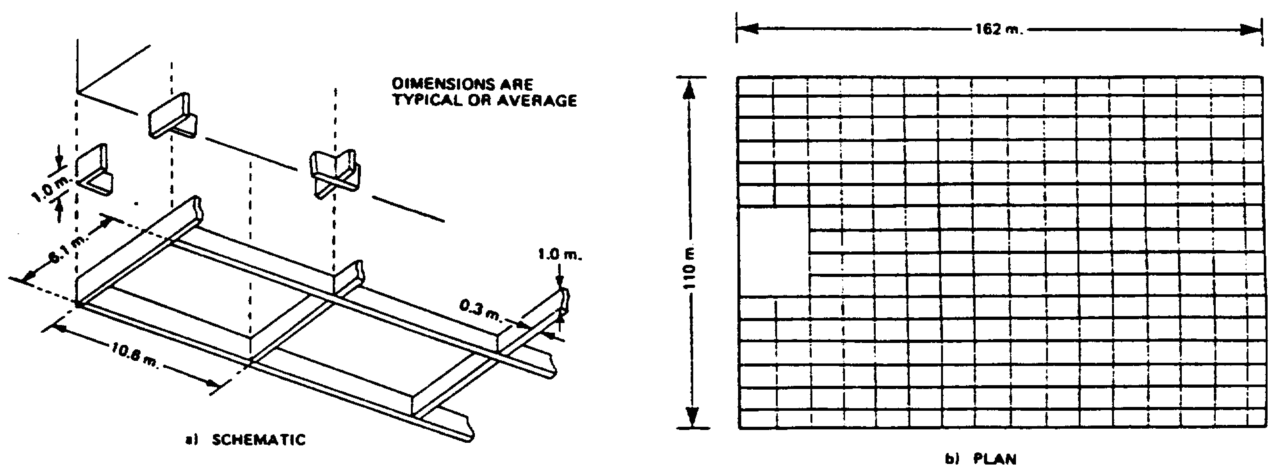


FIGURE 3

ARRANGEMENT OF BASE SKIRTS SSDC/MAT

Table 3

Case History	Maximum Interpreted Ice Load (MN)	
	From Ice Monitoring	From Geotechnical Response
Tarsiut	140	20
Uviluk	80 70 (June)	<30 N/A
Kogyuk	<100 (setdown) N/A 100 (June)	<100 <30 N/A
Amauligak	500+ (Jefferies & Wright) 230 (Blanchet)	<110
Phoenix	70	20
Aurora	<70	<35

PART 4

ROUND-TABLE SESSION

1.0 NOGAP Regional Studies

1.1 Introduction

Neil MacLeod: In the first session today, we want to review the NOGAP granular resource projects that were reported on yesterday, think about where they fit with the geological models that Steve Blasco presented yesterday and try to identify any changes that should be made to the interpretation of those areas from a geological or inventory perspective.

Those who know something about geophysics might be able to recommend equipment and techniques that are being used today would be better than that used to evaluate the area in question. Those with engineering, surveys, or the operator's perspective may want to consider how the data was or should be collected and how the information could be used.

1.2 Yukon Shelf

John Lewis: Over the past 7 or 8 years, there has been very little new data added to the Yukon shelf geophysical data sets or geotechnical data sets as far, as I am aware. So there isn't a lot we can do to update granular resource inventory on that basis. There are a number of questions as to the local small shoal features and the thickness of the lag deposits in the off shore region. I suggest it would be possible to mount some new data acquisition programs in that region, with sampling to confirm the thickness of features. In general, I think there is a reasonably good regional overview of the granular resource in the Yukon Shelf area and I can't see a lot that we can add to that with the existing data set.

Steve Blasco: You are saying that we need new data to actually get at the thickness.

John Lewis: I think so. The geophysical data that we collected out there didn't really give us an idea of the thickness. I think we may have to go back with some kind of vibrocoring program or something along that line to get a better idea of the nature of those off-shore lag deposits. Are they recoverable if they are only 10 cm thick? Is there a dredging mechanism to get at these gravels?

Bill Scott: If they area only a few centimetres, you can't really dredge too effectively.

Kevin Hewitt: If the seabed was flat and you struck off 6 to 8 inches each time, it might be possible. But then even if it was 8 inches thick it would not be much good because you can't guarantee you will not go back over where you just stripped off.

John Lewis: But there are 1,400 km^2 of area so you could put your dredge down and steam for a 100 km without re-crossing the lines.

Kevin Hewitt: I would say a practical minimum thickness would be 1 to 2 m.

John Lewis: At this stage, the geophysics are not showing us any significant thickness of gravel at all. All we have are grab samples throughout much of that Shelf area.

Steve Blasco: What you are really saying is that for the 20 prospects you identified, you need to go back and do two things. You need some high res advanced geophysics using new equipment and you need to go back and sample it.

John Lewis: Then you could do some serious delineation of granular resource.

Steve Blasco: From the geologic model standpoint, we can't do much more to enhance the inventory data. In this area the model works pretty good.

John Lewis: I feel fairly confident in the regional geology that we have developed with the data that we had. It is really just the lag gravels that are in question.

Neil MacLeod: Does that include your interpretation that it is a lag deposit that it is not a reworked till?

Steve Blasco: Sometime we intend to go back and focus on these deposits like we did at Issigak, to try to get at the site geology. As for as regional geology, I think we have a framework in place. When sampling, you would try to differentiate, I suppose, between ice rafted deposits and those that are lag deposits. That is those that come out of Unit L, on the shoal. The regional geology really constrains you in terms of roughly where to look and what kind of deposits to look for. John Lewis has 20 of them to go look at. You just need the site geology.

John Lewis: Would it be worthwhile setting up a project to go look at a couple of these shoals on the Yukon shelf, the mid shelf shoals and the outer shoals? I think we are fairly confident that the alluvial deposits along shore are reasonably good quality granular resource. It is the off-shore ones that are questionable in nature because we have very little ground proofing information on these.

Steve Blasco: When the data was collected on the Yukon Shelf, both geological and bathymetric, it was not with any kind of sand or gravel inventory purpose in mind. We could put a different suite of gear on now, basically focusing on the upper few metres. We might be moving in to some of the new digital seismic systems, chirps and things like that.

Neil MacLeod: Is there enough information on gravel on the Yukon Shelf to justify going there rather than say to Banks Island or Issigak?

John Lewis: Well I think there is a higher gravel content in the region, whether those gravels are thick enough to be recoverable is still in question. Look at the alluvial deposits near shore where you can actually walk along the shore and sample them to get a kind of a quality factor. Why wouldn't you go recover the near shore deposits? There are possibly 400 to 800 million cubic metres of shallow gravel. If you are going to steam all the way over to the Yukon Shelf, whether you go on the outer shelf or the inner shelf makes no difference.

Steve Blasco: The problem in the inner shelf is you get into water depths that dredges don't like. Some of the resources you want to recover are in water depths less than 10 m and the dredges don't like to go in there.

John Lewis: Well we have 400 million cubic metres estimated in water depths between 10 - 20 m and another 400 million in-shore of that in the 0 - 10 m.

Bill Scott: What happens to shoreline stability if you start dredging major volumes from that water depth? I would guess that would be a serious problem.

John Lewis: I wouldn't think it would be much of a problem. If you were out beyond the 10 m contour, you will not be taking armour off the beaches.

Steve Blasco: There is also the strip along the edge of the Yukon Shelf where there are migrating sand wedges. There is stuff all along the edge as you go down the Mackenzie Trough and it is not as far to travel.

John Lewis: Yeah and it is potentially thicker. If you are getting mega-ripples and sand wedges, you are definitely into a thicker surficial material.

Bob Gowan: Was there side scan involved in that?

John Lewis: There was. Actually, we didn't look at it in our program but Jim Shearer did a summary of it for us. He was looking at it from an ice scour point of view and he mapped out surficial features like mega-ripples and what he interpreted as granular or gravels and ripples marks throughout the area. These should be tested further.

Kevin Hewitt: I don't think that the industry or operators are likely to want granular materials in the Yukon Coast area because the SSDC mat has already been used just west of there on the U.S. side. They put it on the seabed and it worked well. There is likely not any reason to drill another hole near there.

1.3 Herschel Island

Neil MacLeod: Can we move on to Rick Quinn and the Herschel Island area?

Rick Quinn: Well, in the area from Herschel Island down to Cape Point, there is a lot of geophysical coverage. Particularly in the deeper water areas where a survey boat can traverse. There is a fair amount of geophysical coverage from the Norweta and various cruises that the operators have had and the Banksland cruise that GSC had. Unfortunately, there are the inherent limitations of the acoustic techniques that were used on some of the most prospective areas for borrow like on the Herschel Sill. The capping of the coarser material tends to preclude the definition of the deeper underlying layers using geophysics.

There are a couple of areas that need more exploration, someday. Between Kay Point and Herschel Sill, there is a vast area that has not been looked at. Collinson Head, off Herschel Island, has not been delineated very tightly. There could be some more material up on that northern tip or the eastern side of Herschel. There are also prospective areas near the Yukon Shelf where you have outwash deposits on-shore that really haven't been looked at to any great extent in a submarine environment. So, in my mind, there is certainly a need for some way of physically sampling to try to delineate the areas that are termed as prospective. We would see what really is on the sea floor and if there is any way of determining some of the thicknesses and the granular nature of the deposits. I wonder too if some of the techniques such as electrical methods could be looked at to help complement the geophysics that is known already.

Another thought crossed my mind for that area too. I think it was Steve who was saying there are actually some very large boulders sitting up on the Sill. These have caused problems to suction dredges in some other areas like off Kay Point. They may be due to either re-working of the sediments or could be due to terrestrial outwash plain glacial deposits. Something like a towed video system may provide a technique of giving some aerial coverage as well as a real world look at the nature of the sediments that are on the sea floor. I hesitate to recommend using the video because the Beaufort is not known to be the clearest water area of the world but nevertheless if it can be towed and contour fly over the sea floor, it could give more information on the nature and size of the aggregates and provide ground truthing for environmental concerns.

John Lewis: When I have been in along the Yukon coast in that area, usually the water is quite clear. I don't know what the bottom water would be like. It could be a turbid zone.

Rick Quinn: The areas that we are primarily interested in is the Sill and the area with potentially course grained material off Stokes Point and between Roland Bay and up to Catton Point.

Steve Blasco: When Gulf was looking for permanent residence sites for the Tarsiut caissons and for Molikpaq, they did quite a study all along that coast to look for a sand seabed as a resting nest. I do not believe they were very successful except for two sites. Gulf did quite a bit of work in there and I don't think we have ever looked at that data. I'm not sure which ship did it but they did eventually find a suitable site. They did move a ship over there and so there is a data set along that coastline that has not been analyzed.

Neil MacLeod: It seems there are a few things to be done in the Herschel Island area to tie up some loose ends. There is a need to confirm the origin of the deposits on the Sill and the origin of the sill to get a better grasp of prospects in the Herschel area.

Rick Quinn: Yeah and also to confirm the spatial distribution of the material. Sometimes you may be in less than 12 m of water.

1.4 Issigak

Neil MacLeod: The next site to the east is Issigak. We have a lot of borehole data from Issigak and I think that we know a fair bit about the physical features of the Issigak deposit. But there are a couple of remaining issues such as the geological interpretation that ties the Tarsiut biostratigraphy back to Issigak. There are ways of confirming this interpretation. In fact, at one time we had data by ESSO that would confirm it, but that data was lost.

A second issue is the question of a source. It is my interpretation that Issigak is a fluvial or fluvial deltaic deposit comprised of sediment reworked from a nearby source some place off the south or southwest end of it. The source has never been identified because it is in an area of shallow water where not much exploration has been done. The problems have always been that the seabed in that area is quite shallow, the bottom is quite soft and the always been that the seabed in that area is quite shallow, the bottom is quite soft and the water is quite muddy. The geophysical guys will have to come up with a new way of sneaking into that area which is maybe only 5 or 6 m deep at the most.

Steve, you have a somewhat different opinion on its origin and I know Guy Fortin has really different ideas on the geology of that deposit. Perhaps you can suggest ways of testing his theories?

Steve Blasco: We definitely need more regional information to link Issigak back into Tarsiut and some other areas so we can map reflectors in and out of the area. We need that kind of regional framework to determine whether Guy's approach, your approach, our approach or whichever is appropriate. I also agree with you, that we need to tie down the origin as an actual fluvial deposit, to find the source of the gravel. If, in fact, it has all been reworked and now shows up as some kind of shoreline, those water depths further to the east need to be explored more thoroughly. If it is some kind of lag deposit, we may find more Issigaks along the same old shoreline.

We have never done much research about old shoreline stands on the Beaufort. We did some work with Pelletier, when he was trying to look at still stands years ago but there wasn't enough information. It would be nice to have that kind of information then we could actually sit down and decide which model is appropriate.

Another thing was, Muharrem Gajtani's hypothesis was that any kind of a shoal element was worth investigating too because it was exposed to higher energy conditions for a longer period of time. So any shoals in the area of an exploration prospect were looked at.

Kevin Hewitt: That is how Muharrem found Issigak. They saw that high there on the bathymetry and just came in to test it.

Neil MacLeod: Guy, do you have any comments about Issigak?

Guy Fortin: Maybe one. I think that a lot of our interpretation is based on one date at Tarsiut. Should we trust that date 100% or is Issigak also based on some other dates on the eastern side?

Neil MacLeod: Well there are a fair number of dates on the Tarsiut samples. The biostratigraphic information has been compiled and there are several different dates on that. If there is an error in the interpretation it is with the correlation of the information at Tarsiut and back to Issigak. I think that the Tarsiut dates are probably your type sections for the Beaufort. That hole is dated and tied down about as well as it will be and probably about as well anything in the Kringalik Plateau will be for the next ten years. Steve, I don't know of anything else you are doing in that area?

Steve Blasco: There are between 20 and 25 industry dates on the Tarsiut section that all tie together nicely. They were done in the early years by Muharrem. But the real weak link is the tie-in to Issigak. If we find that the Issigak area is not linked to Tarsiut or the stratigraphy is changing in there that would require a significant re-thinking of our local model.

I don't think we can really dispute the Tarsiut data. It is a question of whether it is appropriate beyond Tarsiut.

1.5 Isserk

Neil MacLeod: I guess our next stop on our voyage eastward is Isserk. Mr. Lewis will you lead off?

John Lewis: For the study of the Isserk site, we were unable to locate quite a considerable amount of data. In particular, Gulf's data from 1982, 1984 and 1985 couldn't be found. There were boomer and 3.5 kilohertz data but most available seismic data over the shallow upper sand deposit at Isserk was not of particularly good quality. So we ended up doing most of that inter-pretation from the relatively large number of boreholes that were available in the area. It would be interesting, if this earlier data could be found, to re-evaluate some of it. Alternately we should go up and do some re-survey over the area with say the IKB Seistec or a dual boomer system maybe, to try for better penetration and stratigraphic delineation through that upper sand body.

Another objective would be to extend our data to the area of the lower sand body in the southwest corner of the block. We have virtually no quality information on this large area. If there is a chance to put some boreholes in that region, it might be worthwhile. That area does extend further southeast beyond the edge of the Isserk block site. So it may be worth extending the search a little bit further to the south.

When Laughie Meagher and I were originally writing this report, he suggested about 60 more boreholes would be required to delineate it accurately. I think that is probably a ridiculous number to consider at this time. We had a lot of uncertainty in the assessment of the deposits at that point, particularly the qualities of the lower deposit and there was no information on the upper deposit. We felt that some improved geophysical surveying techniques which may have been actually used in these missing data sets from '84 and '85, were needed.

I think most of the seismic data that was available over the Isserk site was somewhat marginal because of weather conditions at the time of the survey. There were a couple of good lines but the majority of them were seriously affected by heave motion. Some re-survey over that site area would really help. You can either plan on good weather or you should make some improvements by providing active heave compensations systems, or data acquisition systems that were not available or were not used at the time.

Neil MacLeod: You might justify re-surveying it if the work was focused on the gravel part of that deposit. You did show that in the lower sand body there was an area with gravel in it. Could more work be done to trace that further?

John Lewis: Unfortunately most of the geophysical data that we had was over the shallow sand body and you couldn't see the bottom of the shallow sand on the seismic records. It typically masked the lower sand reflector because coarser grained material on the seabed really limits your penetration and resolution definition with high- res, particularly with a 3.5 kilo-Hertz profiler and the boomer is often significantly reduced in its effectiveness. So you could have gravel hidden under the first layer of sand.

Neil MacLeod: Kevin, as an operator, do you agree that the prospects of gravel at Isserk might drive further research.

Kevin Hewitt: Yes. There is enough sand there. Gravel is what will be scarce resource.

Bill Scott: Scarce enough to justify several metres of stripping because if I understand it right, the lower gravel is a fair way down in this thing.

John Lewis: We only really saw it in one borehole which turns out to be the common point of all three profiles I showed.

Neil MacLeod: I guess, you have to evaluate that. If it turns out that this is the only high spot with gravel on it and everything else is 15 m down obviously you wouldn't chase it. But we don't know that yet. There is probably some justification for further work at Isserk. It would be much greater if someone was proposing to develop there but it isn't far from Amauligak to go for gravel.

John Lewis: That is my feeling. There were extensive recommendations made at the end of our study that could not be justified now. I could see possibly going back and doing a couple of test lines with new geophysical technique whether it be resistivity or a better seismic profiling system. In fact you might want to go out to an area like Isserk or Issigak to test it there because you have a well known area. So those two areas may become test areas to look at new processing and new techniques in the future.

1.6 Erksak

Neil MacLeod: John, do you want to move on to Erksak?

John Lewis: O.K. The Erksak area study was very much a broad brush regional evaluation. It is a very large area to start with. Throughout the southeastern portion of the area there was very little geophysical data or geotechnical data. Most geotechnical data is grouped in a number of small regions for site studies.

The prospect zones were particularly lacking in boreholes. I think there were two boreholes within the Erksak Channel that, if I remember correctly, both had marginal quality granular resource. The Erksak Channel looked like old braided river streams, sandbars, etc. A few more boreholes or additional work in that region is required to delineate these prospects.

You would have to do some very detailed delineation work before you would actually try and use any of the resources outlined in these prospects. I'm not sure how much effort should go into that area. It tends to be all fine-grained sand and very little gravel was observed.

Neil MacLeod: Can you put some sort of quality assessment on the resource prospects?

John Lewis: We did try to do that by looking at the seismics and the nearby boreholes and estimating the quality. We still ended up with something like 7 billion cubic metres of potential granular sediments. It is a huge area and there is a lot of sand exposed on the seabed. Quality would have to be looked for each area. You would only do that if you wanted to go in and look at a very specific area.

Steve Blasco: Do you have enough of an understanding of the geology there to be able to say that we have identified all of the potential targets in there? I would hate to discover that there are some gravel deposits that were missed.

Bob Gowan: Yeah. Is there anything to suggest that the proven areas are the best areas in terms of likely gravel targets?

John Lewis: The only reason those were classified as 'proven' was because they were the only ones that had any borehole data.

Bob Gowan: Have you considered whether there are better prospects for gravel based on the physiography or landform? Perhaps these bars that you have shown in the channels or a terrace on the edge of the Issigak high or something.

John Lewis: There certainly might be areas where some borehole work would be interesting. We do have a few very good seismic records showing these pro-grading beds on the edges of the channel features. You have a very good indication that it was probably well washed out and reasonably clean material. But we don't have much to confirm that.

Steve Blasco: Are you talking about that in general terms or about the edge of the Kugmallit Channel on the Tingmiark Plain?

John Lewis: I think along that whole edge there is a relatively high probability for reasonably good quality resources. But we have virtually no boreholes there. We found working on this large an area extremely difficult. As a geologist or geophysicist, you look at the Beaufort as a stratigraphic collection of 8 units (A, B,C, etc.) and your mapping is stratigraphically oriented. In this case, we had to impose engineering considerations on it. It became very complex to deal with this.

Steve Blasco: Ground truthing seems to be a bigger concern here than is more geophysical work. The questions we usually get are "where is the coarser grained material" and "where is the sand with the lower fines content." Most of the Unit C sand there has a fines content of 6, 8, or 10%. Yet if it has been re-worked at all, it could be as low as 2 or 3%.

John Lewis: Well I'm certain that our understanding of the area would benefit from higher quality seismic data including the data that we couldn't locate. The majority of the lines in that region I think were Gulf '80 and '81 data sets. There were a few Dome lines and a few Esso lines. I know that the whole area of the Uviluk high was all surveyed by Dome in '81 cause I did it. Unfortunately we couldn't find any of that data set.

Now you could evaluate some of the site survey data to find answers to your detailed questions. For our study we wanted to get a regional perspective and we didn't go in and look at them in the detail that you are asking for now. You could go in and look at all the data from the Kogyuk site or the West Tingmiark site or if you could find the Uviluk data set from the perspective of trying to delineate gravel from sand and consider it from a quality factor. We couldn't do that because the area of our study was just too big to look at it in that detail.

Steve Blasco: Was there any potential in the James Shoal area?

John Lewis: Oh yes. There is quite a large potential, although the James Shoal area does appear to have a veneer of clay overlying it. There are some sand areas down the southern portion of the shoal and around the Alerk site as well. There were a lot of boreholes there and there was some dredging.

Steve Blasco: What about the whole Kaglulik Plain. We never really looked at the area which is further to the east. We start to get more inter-bedded sequences as you go further east.

John Lewis: And there is a lot more permafrost, if I remember correctly.

Neil MacLeod: We did a couple of holes out that way for Chevron at the north end of Tuktoyaktuk Peninsula, both on the west side and the east side. To my knowledge there is no shallow seismic out that way other than some of the regional lines that Dome did initially.

Steve Blasco: And we have some regional lines. They have never been looked at from the sand and gravel perspective though.

Kevin Hewitt: We did a couple of boreholes initially in '80 out there and encountered very fine and very dense sand.

John Lewis: In the Baillie Island area you tend to get better penetration with the acoustic methods than you do through that Tingmiark Plain area. That always implied to me that you are getting a fining or less sand content and less permafrost.

Steve Blasco: But that is a very general picture. I wonder, in fact, if there are areas within the Kaglulik Plain which may contain potential granular resources. It is a question of whether there is a more appropriate way to do some regional work there.

John Lewis: Again, it comes down to a question of whether that is likely to be an area where there they will need granular resource?

Steve Blasco: Well, it may be easier to bring material in from there than it is from Herschel or Banks (Island). I don't think we have enough information to categorically state that we can neglect the Kaglulik Plain as a source of sand and gravel. I wouldn't want to make that statement. So it is a question of how to put ourselves in a position to either say there is or is not a source there.

1.7 Banks Island

John Lewis: Guy, do you want to say anything about the Banks Island area?

Guy Fortin: Banks Island is very far east and there is very little data. We have one regional line along the coast, no boreholes and only a few samples from a grab sampler. This makes interpreting the geology very difficult. I don't know much about dredging but I wouldn't send a dredge out there without a good map of the pockets of sand and gravel. A lot of mapping must be done if there is some interest there. If the pockets are wide enough to be dredgeable, we need almost complete coverage with side scan sonar and some resistivity or seismic tools. I don't think a 3.50 kiloHertz would do the job. Maybe a system like a boomer with a minimum penetration of 3 or 4 m in coarse sand and gravel with a resolution of about half a metre. I don't think it's worth it to core all of the pockets. Maybe we should think about doing some coring and establishing correlation curves which may help to interpret either the resistivity or the refraction data.

There are in fact three settings to consider. At the mouth of the Masik River, there may be a fluvial glacial terrace. I think we have to drop the off-shore extension of Carpenter Till because I don't think a dredge can work where the sea bed has a relief of maybe 10 m. That leaves the Sachs Till extension which is flat and should be a good source for high quality material. In fact, all the area between the Masik River and Sachs Harbour has a good potential but there is almost no data there.

John Lewis: There were some dredge tests in there, weren't there? They found quite large boulders.

Guy Fortin: Yes. I don't know if the boulders represent problems for dredging. Is there is a way to filter a seabed boulder of a half metre when sucking up sand and gravel? And I don't know if those pockets are too small or not wide enough for the dredges.

Neil MacLeod: The biggest problem Dome had with the dredges was that they couldn't re-locate an area where they found good material, because of their accuracy of their positioning equipment, the sea state conditions or because it was so close to the shore. When you start going into small pockets, you really have to know what you are doing. If someone was going to get serious about dredging over there, better positioning is essential.

It is my opinion that dredging in those small pockets is pretty inefficient. There are a thousand complications to dredging at Banks Island like the ship time to get there, these small pockets are hard to hit and the closeness to the shore. I think the operators would have to be very desperate before they would ever make too many trips back there. I think Banks Island is your source of last resort. If it looks like there are other options and I think they will explore those pretty far before they go back to Banks Island.

Kevin Hewitt: As I said before, we would like to know where gravel is. We already know where the sand is. If you ask yourself why we would need the gravel, we will probably need it for erosion protection. There will be a lot less demand in the future than it was at that time because we had major erosion problems with the shallow draft structures then. With the SSDC/MAT we don't need any erosion protection. The Molikpaq has 20 m draft, but only needs a little erosion protection around the base. I think if you are looking at production structures you will probably need some but they will probably be designed such that you don't need large boulders. If you did, there would be something wrong with your design.

I'm just trying to put Banks Island in perspective. Previously we had a serious problem with erosion because of the draft of those structures. We were willing to go across to Banks Island because it seemed like the most viable prospect. It worked to a degree but it is not likely to be an effective prospect for the future. I say not likely.

Rick Quinn: What would be the advantage of having a detailed bathymetric map of the area between Masik River and Sachs Harbour apart from navigation concerns?

Guy Fortin: We have to think about a system which combines both GIS and GPS to have a map on shipboard and an update of the positioning to be able to dredge those pockets. It would be necessary to have good bathymetric maps for dredging because of the high seabed relief. Besides that, I think it would also help to mark the off-shore outcrops of till because I think they have a small relief. It could be a way to map the outcrops and the pockets instead of seismic. It would be easy to map the narrow shoreline with maybe one pass.

2.0 Technology and Techniques

2.1 Introduction

Neil MacLeod: I think we can move on to the next part of our planned discussions. We should be trying to focus on ways for developing and applying new technology in the exploration or assessment of granular prospects in the Beaufort. First I suggest we look at seismic techniques. Consider the application of newer techniques for mapping granular resources in the Beaufort Sea. John, is there anything that has come on the market or about to come on the market that would revolutionize our ability to predict where granular resources might be found?

2.2 Seismic Methods

2.2.1 Equipment

John Lewis: Well I suggest that from an acoustics point of view there are ways to improve the quality of data by adding heave compensation and using the line and cone array systems that have been developed over the last couple of years. We have obtained quite good data with that. I still think using acoustics for stratigraphic mapping will be severely restricted in areas of coarse granular material. Therefore, you would probably have to move on to resistivity techniques or borehole confirmation to get your stratigraphy through those regions. You can't usually determine the thickness of a deposit very well from acoustics. You can usually see the top of the deposit but it is very difficult to delineate the bottom of the deposit with acoustics.

Rick Quinn: Something that we haven't fully talked about is the resolution aspect of acoustics. That is things like pulse width and power output but we might want to look at the frequency spectrums to help us delineate gravel deposits. If you are in an area that requires penetration, hitting it with a bigger hammer often creates more problems. Perhaps if you could use some of the digital techniques or signal processing techniques and look at frequency bands that may be best tuned to look at more deep-lying gravel deposits, you might get more dividends. Use the frequency spectrums that will give you penetration and then try to fine tune the resolution component of it. That is digital processing.

John Lewis: The chirp system does that.

Rick Quinn: Yeah. But there is also a big band width in the line cone survey. You have a big dynamic range there as well and it is probably at a lower frequency than the chirp.

John Lewis: Not particularly, the line cone acts as a natural filter and cuts out almost everything below about 1800 hertz. But I can still get, often 40 or 50 m penetration in clays.

Rick Quinn: Yeah, but we are not looking for penetration in clays. What we want is to get better penetration and enhance the resolution in the gravels.

John Lewis: But that frequency cut off is also a function of the size of the cone. If you make the cone bigger that frequency goes lower.

Rick Quinn: I think the component you want to enhance is the low frequency component, if you want to get deeper down to look at some of these.

Bill Scott: You run into wavelength problems though at lower frequencies. If you are looking for a layer that is a couple of metres thick, the wave length gets to be comparable to the layer size or bigger. If you blink you miss the layer.

John Peters: How important is heave compensation relative to all of these other fine tuning things? I mean, will you get tremendous improvement just by having heave compensation.

John Lewis: If you are looking at high resolution systems it is extremely important.

George Eaton: I think that is an easy problem to solve compared to some of these other things you have been talking about.

Steve Blasco: The question is how to import heave compensation into our system or should it be corrected outside it.

John Lewis: Most seismic systems have a separate source and receiver. You have one going up and the other going down and they are not going up and down in conjunction with the vessel.

Steve Blasco: George, what is the stage of development that the Hydrographic Service has achieved with the heave compensator?

George Eaton: Well there are a number that you can buy that will work reasonably well these days. We ran one in '89 on the Tully that showed remarkably good results. Most cost in the neighbourhood of $20,000 but I think realistically the problem could be solved with GPS.

Steve Blasco: On the acoustics side, there are also refraction methods.

Guy Fortin: Refractions can help to distinguish between sand and gravel. If anything there is no sub-bottom penetration with a refraction systems. It is good when you use both methods to help interpret the layers.

Steve Blasco: There are changes from a reflection side too. One big change is the switch to digital acquisition systems which should be experimented with. The new digital acquisition systems in the GSC is the new ORE systems. An idea would be to try and focus some of the new digital equipment as opposed to analog on the gravel problems. You mentioned line and cone but there is also the Datasonic chirp system. I am concerned from what I have seen of the chirp system about its ability to penetrate sand and gravel but maybe from the digital processing standpoint there some possibility. We are planning to get back into digital processing where you can start enhancing digital data and manipulate the weaker signal from below the hard return.

John Lewis: You still have to be concerned about the actual source/receiver combination to do that.

Steve Blasco: Yeah. That doesn't destroy the system. It is just to give you an option for playing around more with the data.

John Lewis: A lot of the older data that was collected out here was recorded on analog tape. That could be digitized.

Steve Blasco: In fact, Gulf went through quite a study. They took a series of boomer data and had it digitized by A-Cubed of Toronto. It was a $22,000 project. The digitizing of the analog data chewed up $19,000 and the processing and interpretation chewed up the other $3,000. The answer was that the analog data wasn't that good to start with and you can't make something better than what you started with. So there was no point in the high cost of digitizing for that project. But the whole process was there and they certainly demonstrated that if you had very good analog data at the start, you could do something with it.

Neil MacLeod: But I think the point here has to be that there isn't anything strikingly new on the market. There are no startlingly new processing or data storage techniques that will revolutionize anything we are doing. There has been general progress but there is no reason to go back to any particular site now with new equipment because now there is a way of seeing something that we couldn't see before.

Steve Blasco: Well, it is a little more than that. There is also equipment, like sleeve guns. We could get out of air guns and into sleeve guns. No I believe it is a little more than what you are saying. There are in fact enhancements in equipment and enhancements in signal processing that are appropriate and worth testing. You could select a suite of equipment and focus it specifically for gravel.

But Neil raised a valid question. Is equipment substantially improved enough that we can go back and re-do Issigak or Isserk and nail it down for all time? I don't think it has reached that level. Although, it has probably reached a level where we can add to what we know.

John Lewis: Another aspect of the seismic techniques is to try and do things like heave compensation so that you can really look at that fine scaled stratigraphy. Because that is in the shallow zone and particularly in Unit B when you are looking for reworked units trying to determine if there is any gravel in there. What you need is very good quality data that is heave compensated to the point that you can look at it like a drawn seismic section. If you have a system that will give you 6 cm or 10 cm resolution but it is going up and down 50 cm, you can't make much sense out of it.

It is my impression that we need to focus on ways to improve on the resolution and interpretability of Unit B. If you are going to get into the stratigraphic definitions of reworked thin sand bars and deposits and try and make sense out of them, you have to have the heave compensation. You have to have the highest possible quality seismic information that you can get. And we have a couple of examples which were collected over the years because they happen to be out there on a day when it was just flat calm. The amount of stratigraphy that can be interpreted out of those few records is phenomenal. But that is one out of ten lines and you can't interpret a whole region based on one out of ten lines. I think that technology is around and can probably be put together to work with more consistency than we have had in the past.

Neil MacLeod: Guy, have you any ideas? You have worked with different equipment and you are working with some new equipment now. Can any of that be applied to the Beaufort?

Guy Fortin: I think the problems are a bit different. We are looking for very soft sediment. But in the Beaufort we are looking for sand and gravel. So I cannot disagree with John about the need for higher resolution. The only problem is it is very difficult to resolve those thin layers of dense sand and gravel.

John Lewis: I think your ability to penetrate and interpret the depths of the sand will improve if you can get the heave compensation and you can get the finer detail on your stratigraphy. Now, a lot of time you can't interpret stratigraphy other than on a very broad sense. You might know you have your 'C' Unconformity, a major reflector. But when you have half a metre of heave on the data that is about all you can get out of it.

Steve Blasco: That brings another point to mind. One of the ways to improve the quality of seismic data is to cut your speed in half. We don't get as many lines. Instead of running at 6 knots, we run at 3 and we do get a better spatial resolution. Those are some of the things we need to do, just be satisfied with fewer lines and better quality and solve the problem, rather than going after huge volumes of data.

2.2.2 Storing Geophysical Data

Neil MacLeod: I have a question for the geophysical operators. Are there new techniques for electronically storing data that would make it more feasible to keep some of this stuff than the older methods where everything was kept on paper? Certainly we are just a generation away from disks and things like that for storing that stuff. But where is the industry going now?

Steve Blasco: You can actually take a seismic section and scan it and passively record it. You may have trouble interacting with it and it is not all that good because you don't get the original dynamic range. All the subtleties have disappeared from the scanning.

John Lewis: There are new recording techniques out there, new digital recording systems and that sort of thing. But a lot of those are still pretty rough. When you try and store the information that is in a seismic record or side scan record you have to store one hell of a lot of data. You can acquire up into the Gigabyte range of the data within a few days of surveying. So, the techniques are still a little difficult to deal with and I'm not entirely convinced that when you have to go back and run all the stuff through a system to get a display wether it ever really gets looked at in detail again. It is one thing to pull out a record and hold it up and you can say within a few seconds if there is something on it that you want to get. But if I have to go and fiddle around with computers and disks and wait for ten minutes for it to regenerate a profile, I probably will not even look at it.

Neil MacLeod: That means the paper records are very valuable because without them we don't have an easy method of re-examining the data.

A bad practice that some operators had was to run their budgets for their seismic work to the last nickel while at sea. They did not budget for putting together a report on the project with any interpreted sections, or whatever. I know Rick Quinn's firm did some for Gulf and those are very valuable reports when the data is lost.

If all the operators had just taken 5% of their ship budget and used it for an end of project report, we at least would have our basic interpretation and sections some place in a library. It would not likely be shredded if it was in a report format.

Rick Quinn: In the fall, I had a call from a fellow at Gulf who had been asked to go through a lot of Gulf's high resolution surveys to create some kind of an inventory and to get it organized. He wanted to know if we had a copy of an Operations Report for Gulf work done '81. Sure enough, we had a copy. The good news was that Gulf was putting all this together so there may be some chance of finding it.

Steve Blasco: I expect Chris Burquist has taken over all of that. We have a current project at Amauligak and we have been accessing seismic data, borehole data and all that through him. He seems to be quite aware of what is there and not there.

2.2.3 Shallow Water Surveys

Bill Scott: Well, there is likely to be some near shore work because Steve Solomon is planning a drilling program in a year's time to keep us honest in all the predictions on the survey.

Steve Blasco: But that is all in less than 5 m water depth. I don't think any of it was to be deeper than that.

John Lewis: That brings up a thought. For the Issigak area, you said it would be worth doing more work in-shore to try and see if there is a source for that gravel. Using the Arktos vehicle it might be possible to set up a program to survey in the real shallow water between the deposit and Pelly Island.

Bob Gowan: How shallow can it work?

John Lewis: You can run it right up on shore.

Neil MacLeod: What you could do there is to run off Garry Island or Pelly Island and some of the spits. It would help us understand the morphology of some of these other deposits. Is what we are seeing at Issigak typical of a spit or similar secondary deposit like the Immerk Pit or is it more like a channel deposit? It sure would be an interesting exercise.

John Lewis: I'm pretty sure we could access the area using an Arktos type vehicle and work in water depths that we haven't been able to survey in the past.

Steve Blasco: Are these areas too shallow for dredging?

John Lewis: We are looking at it from a geology point of view to try to sort out the models for the Issigak area.

Kevin Hewitt: To answer that question, I think there was a limit for dredging before because of the specific equipment we had up there. There is no dredging equipment there right now. If we had a deposit, we could bring equipment out specifically for it.

John Lewis: Well the Arktos won't be there this year. Apparently it is to be repaired.

Steve Blasco: It went to the Coast Guard last week and they are putting up practically a quarter million dollars to refit and refurbish it. The engines and everything are supposed to be completed by late fall. It should be available next year. However, we have to request it to make sure it stays in the Beaufort.

Bill Scott: Some of this work could be done off the ice too. You know, there are lots of areas where the ice is good enough that you could do a winter program. A lot of the problems go away if you work off the ice. I don't know about acoustically but electrically you can get some very high grade data off the ice.

John Lewis: Well there are a lot of problems with acoustics through the ice. Plus the production rates on winter programs tend to be considerably slower than conventional marine work.

Bill Scott: You are trying to resolve a detailed situation of multi-layers in a relatively confined area. You don't need 100 km of line per day.

Bob Gowan: Is Steve Solomon's winter program set for next year? Is it off North Head?

Steve Blasco: I think they haven't decided yet but it is definitely in that region. He wants to ground truth the stuff he has.

Bill Scott: We could certainly find some winter electives to that. We might nip around the corner and look at this strand line that I was talking about too. Throughout most of that area, the ice is pretty good.

Bob Gowan: The logistics have been looked at to Isserk?

Neil MacLeod: All through there you can work on the ice. You can get out to Isserk some years. We had trouble in about 1 year in 5 getting out to the Isserk area. But anything inside Isserk is quite accessible over the ice. We got to Issigak over the ice 2 years out of 3. That was getting to the limit, though. You should not count on it.

Bill Scott: Well certainly all of Kugmallit Bay will have solid ice. ESSO have worked in winter all through there.

John Lewis: It might be worth taking the new hydrographic data and re-evaluating it and looking for new targets as well as going out and doing some ground truthing on targets that are already known.

2.3 Resistivity

Neil MacLeod: It seems to me that seismic methods are unable to give us information about the thickness of granular deposits or about the nature of inter-bedded granular deposits. Bill, I understand that resistivity may be able to complement seismic work in these areas.

Bill Scott: I think there is some hope for using resistivity for mapping the thickness of granular deposits particularly in areas where we have a bit of control. You need to tie it at some places so you have the confidence of interpretation through the areas where you can't confirm it. But there certainly is a reasonable possibility that you can do quite detailed mapping of near surface layers.

With resistivity you can resolve layers of thicknesses comparable to their depth of burial. As you get deeper, the interpretation has to be broader brush. But certainly if you are talking about, say the top 10 m, you can get quite nice resolution and very detailed. If you are looking at the top of permafrost at 150 m, you will be plus or minus 10 or 15 m and you are not going to find thin layers at any depth.

Neil MacLeod: Bill, would the marine resistivity techniques see through the upper sand layer at Isserk better?

Bill Scott: Yeah. You would have a chance of separating the two layers, particularly if there was a clay layer in between.

John Lewis: There is a clay there between the two sand bodies at Isserk.

Neil MacLeod: Could you pick up a gravel layer between two sand layers? There would have to be some minimum thickness, I know, but what are the capabilities?

Bill Scott: You could resolve fairly thin layers provided they are electrically different enough. It is easier to answer the question if I have samples and can actually measure the resistivities and see what the differences were. But, generally you can tell sand from gravel. If there were some stuff in between with a bigger contrast, like clay, you would certainly be able to separate that into layers. For that sort of thing, I would really go to a bottom towed system which I am looking at trying to develop now anyway for work in Lake Ontario.

John Peters: Do you need to make your resistivity measurements in situ or can you use the existing samples to get a realistic model.

Bill Scott: If there were existing samples and I could reconstitute them with the right salinity of water it would give me a very good idea. Then I could do some predictive modelling before the field work and set up a system to enhance the thicknesses we are looking for. Your vertical resolution depends on the separation between electrodes. So if you know you are only going to try and resolve the top 6 m then you build an array that does just that. But if at the same time you want to look at permafrost, then wherever it is, your array has to be very different.

Neil MacLeod: We should be putting some thought into getting that kind of calibration information whenever we are doing geotechnical work in the Beaufort. If resistivity is to be a widely used tool, we all should think about getting samples for calibration.

Bill, you have some good ideas for the next stages in the development of resistivity methods. Will you review them for us?

Bill Scott: What I'm really interested in now is getting continuous information that starts in 3 m water depth and ends up on dry land. This year we got one profile with the electric using Arktos. It started in the water and ended on-shore. We learned there are a lot of easier ways to do it than the way we did it the first time. But I would like to look now at streamlining that and adding seismic to it. I have some preliminary ideas to get a continuous seismic profile through that shallow water zone and up on the land as well. I am going after some money for that independently.

Neil MacLeod: Well, it is an interesting problem that you are trying to solve. It is also very important because anything that is developed in the Beaufort Sea will either go out by ship or go out by pipeline. All those pipelines have to cross that shoreline. I think that transition zone is where we will find the key design issue of a marine pipeline. Ice scour is something we can handle. But the changes in the permafrost front, at the shoreline transition, may be very difficult for pipeline design.

Bill Scott: Part of assessing coastal stability in trying to find a place where you can bring a line ashore where it would last for thirty years without having major problems. I think that is why this is such an interesting area technically. I'm really keen to work on this.

Steve Blasco: The last two years were the first years we actually have any seismic data other than Jim Hunter's for our refraction information. We actually can run a profile from the off-shore to the on-shore and see the permafrost. Off the Tuktoyaktuk Peninsula we can see the permafrost at 49 m coming up right to the shoreline.

Bill Scott: I picked up a lot of information on the deeper permafrost with the electric there and I'm pretty confident about the depths with that. That is the easiest thing to find because it is such an enormous contrast.

John Lewis: I don't really see much point in trying to push the seismics on-shore if you are going to hit permafrost which is down a metre or so. You won't get anything you don't already know. With Arktos, we can get to within about a half a metre of water when the whole frame system starts lifting out of the water and then you have to shut it off. I think that is pretty good. Particularly off the Tuktoyaktuk Peninsula, we could walk in because the water depth was about 2 m until you were right into the beach and then it just kind of popped up. At Richards Island, the shore isn't much different. So you might be a couple hundred yards from the beach when you actually stop profiling.

Bill Scott: There were some areas where we went over spits that were just sort of breaking the water. It would have been very interesting to keep the seismic going through those. Another reason to do this from my point of view is that interface is also of real interest in mineral prospecting. Generally speaking, when you do electrical methods in lakes, you do it in the winter time. You can't do it on-shore in winter or you do it in the summertime on-shore. And you can't get at the water until you get far enough out that you can float something, so the transition zone is an area really to focus on in terms of equipment development.

John Lewis: Well, for most coastal areas of the world, that is a surf zone. You can't get through it anyway, because your equipment is getting beat up on the bottom.

Bill Scott: That is not true in the Beaufort and it is not true in a lot of inland water. There are a lot of inland waters problems that are comparable. This kind of approach has never been offered before and yet would be very useful. Any time you do sewage outfall design for example, that area is the actual focus of the design.

Another thing we have already started to look at is getting a system on the bottom for deeper water. Right now the practical limit is about 20 m of water depth. Until we get a bottom-towed system, we can't go farther out than 20 m of water depth and still count on much resolution of shallow bottom layers. I have already undertaken to have a bottom-towed system for next summer, so it better not be a difficult problem. But I think it will be a while before that set up is routinely deployable with confidence.

Neil MacLeod: Are there any problems with speed of traverse with resistivity? How does it compare with acoustics?

Bill Scott: We ran it at 3 to 4 knots this time around without real problems with resistivity. At the moment it is not technically feasible to do the polarization measurements at that speed. But you can run resistivity at any speed that you can comfortably run good acoustics.

John Lewis: In shallow water and those kind of environments, you are limited to about 3 knots, in general.

2.4 Geology

Neil MacLeod: Steve, let's go into the geological stuff. Is there anything else we should be doing?

Steve Blasco: Most of our work has really just been a wider application of things we have been using all along. We are starting to put together what we call sandwiches of pollen that we find in Holocene sediments like Wisconsin sediments. There are now certain assemblages or characteristics that we can identify when we see them. For example, there is a wet tundra assemblage. Now that we know that it is wet, we have a much better idea of its age. We now have a link between depositional environments and age that is becoming understood much better.

It is a case of using the tools we have been using all along. We are still using standard things like forams and pollen and other dating techniques. We tried a whole series of them. We tried thermal luminescence, we tried uranium dating, we have tried amino acid dating, none of them turned out to be very exact. We even tried lead 210 dating for recent stuff but there isn't enough lead 210 for the measuring equipment to detect in a lot of cases. We have tried a lot of stuff without a great deal of results. Biostratigraphy and radium carbon dating are still the focal point of geologic information.

Neil MacLeod: Yesterday you presented 14 variations of geologic models. Some are more right than others for each area. What is happening to refine these?

Steve Blasco: A fair bit of work has been done on the geological models of the surficial sediments in the Beaufort but there is a need for additional geological work to constrain the models to constrain the inventory. The gross stratigraphic framework for the shelf is in place, but the models suffer from this big problem about the correlation between on-shore, off-shore and shallow water. More work in shallow water should provide the answer now that we have the technology for work in shallow water.

John Lewis has shown us that Arktos can do the geophysics and we can also put cones on it and do some geotechnical work too. I would be inclined to do the geophysics first and then go back and ground truth it.

Obviously whenever you come up with datable material we still want to date it. This chronology gap between land and seabed is a serious concern and it is not just a concern in the Beaufort Sea. There are other areas, like the East Coast, where it has become a huge problem.

The answer to this key question appears to be in the area north of Richards Island. The question carries with it major implications to sand and gravel inventory. If we do have Toker Point sediments indicating a relatively recent glacial advance out there, they could be a source of material like the hidden source of Issigak gravel. It would show that our geologic models are wrong.

Neil MacLeod: That whole range of issues has to be sorted out, because I think there are a lot of us headed in the wrong direction because of the geological models.

Guy, you have looked at the geology too. You have your ideas which don't always agree with Steve's. Where do you think we should look for the key to resolve this and what work do you think is necessary?

Guy Fortin: I agree with Steve that we have to find out what is happening between Isserk and the shore because that is where the two models are contradictory. Some of my interpretations, in the last couple of years before I left the Beaufort, were based on the feeling that there is a glacial limit out there. We have little evidence for it but I think we should search for that evidence.

My interpretation comes from one set of data which combined refraction and reflection data. The only way to explain the channels and the geology is by having an ice sheet there as a source of melting water. I think there is gravel to be found very close to that limit and probably not much off-shore of that limit. I think we should look closer to shore particularly southeast of Isserk. I think there are a couple of highs in that area which could be a source of good gravel.

John Lewis: That is right along the pipeline route.

Guy Fortin: Yeah. I think if you draw a line from the limit of Toker Point till on-shore out to the highs near Isserk, you define the glacial limit there. That limit looks good at Issigak too. Maybe all those are related. I think that because only an ice tongue could bring boulders of the size we get at Issigak, that far off-shore. There must have been some highs sitting there as recently as 30,000 years ago.

Steve Blasco: That is where the problem is. You end up with all those deformed layers which seem to sit on stuff that is younger. If you imply that it is caused by glaciation, you are putting ice in the area at 6,000 years ago. If that is true, then everything on-shore is in error and it will be hard to convince Terrain Sciences of that.

The problem becomes even more complex when you try to invoke the model. So there is either something major wrong with the chronology or with the stratigraphy. Perhaps we have inliers and outliers and we are not recognizing the fact that the stratigraphy is not continuous. Again, we are talking about two end members of the model.

2.5 Grab Sampler

Bill Scott: What is the state of grab samplers? We have been working on a hydraulically operated grab for getting coarse-grained samples. We are using it in placer deposits. It picks up cobble sized samples and still gets 30 cm into the bottom. The design is such that it pulls itself down while it is closing so instead of bumping across the hard top it actually sucks in and pulls up. It works like a couple of backhoes and they operate against each other as they pull down and in. It strikes me that if you have any kind of gravel, your standard light weight samplers don't really give you a return. Would there be some interest in a system like that?

Steve Blasco: Certainly, would be worth trying in terms of sampling technology. I have always had trouble even with vibrocoring. What is the size of it?

Bill Scott: Well, the one we have is 20 litres but we are building a 50 litre version as well. One of the problems with most sampling tools for coarse grained materials is that the fines wash out on the way up. That way you don't really have an idea of what the soil is. It is one of the reasons for building this thing so that there is no wash-out in the design. All it needs is a winch and a hydraulic pump. We are using the power pack off a log splitter. It closes in less than 15 seconds.

Rick Quinn: I would like to have a look at the hydraulic sampler out in the Fraser Delta before taking it up north.

Steve Blasco: Well actually I was going to try it off the end of the dock in Halifax sometime towards the end of March.

Bill Scott: Gordie is going to get a launch and we will do the testing in places he has found difficult. It is not so much an unproven quantity; we are using it regularly. I'm prepared to offer it to take off head-sized boulders and the stuff in between.

Steve Blasco: Also I would be interested in how disturbed the sample is.

Bill Scott: When the next scour experiment is done in the tank, we will put down a very thin layer of black every centimetre and then we will dig holes in the corners. To see how much distortion there is, we will core through what comes up in the sampler.

2.6 Bathymetric Techniques

Neil MacLeod: George, CHS has its own budget and works in its own way. I expect you have probably heard today where your work ties in with the needs of this group. Is there anything in particular that needs some sort of commitment or support from this group to help you?

George Eaton: Well, I think there is a trend in the Hydrographic Service at the moment to turn more inwards than out. I think the days of data acquisition are over, although some work is still possible. I think you will find that we will be mucking more and more with the data we have already. If we get that into order it will become more accessible to you people. I don't think there will be any big acquisition programs for awhile.

Neil MacLeod: George, could you review recent developments in the bathymetric trade?

George Eaton: Well there are a number of techniques that might be of use. Perhaps the one showing the greatest promise is the Through Ice Bathymetric System (TIBS). It is being used in its first production survey this year in Pelly Bay. Depending on the results of that, it will be used again next year off the Garry - Hooper Island area I think. That is all subject to change of course and on funding. GPS will have an affect on all of this too. It means that we can get better position than we have ever had before anywhere in the Beaufort at any time.

I think you people should all make your acoustic requirements better known to us before we go out to do an area. We can help you out more than we have in the past with things like swath sonars. We can also survey in more detailed fashion for you than we ever have before simply because of GPS and some better acoustic techniques. You should consider that some of this data is available in a digital form which has not necessarily been so in the past.

Bill Scott: Would you be amenable to offers to put other equipment on at the same time?

George Eaton: Yeah. There is an accord that was signed years ago between Fisheries and Oceans and EMR that allows some co-operation that goes back and forth.

The Tully will not be in the Beaufort Sea this coming year but that is not to say it won't be there in future years. Depends on how loud you request it and the validity of it. I wouldn't be afraid to make your requests well known and well in advance, strongly.

Steve Blasco: Actually we were asked to put in a 3 to 4 year long term plan for ships on the west coast. We did that and never heard anything back.

George Eaton: Well I think it is important to follow it up. Who knows what did happen to it? Talk to Don Garrett.

Steve Blasco: What about things like Rick mentioned yesterday. Systems that penetrate where you have suspended sediments. Are there advances being made there and systems that will ultimately be able to see through the fog?

Rick Quinn: I wouldn't hold much hope there. You could get a bigger more powerful laser but there is only marginal return on the more powerful laser. It's like using an axe to cut flowers. It's the wrong way to go for murky waters. You might as well go to swath sonars and potentially TIBS.

That is interesting because sonar may give you the water bottom. I know the resolution of that is directly dependent on the water depth but you know there is more information in that electromagnetic signal that could very well help you to pull out more sub-water information. It is of no interest to the hydrographers what is happening below the water/mud line; however, it is for gravel exploration purposes. That is an area worth more consideration. The initial use of the electromagnetic system was on land to find mineral deposits. It was suppose to look through the sub-surface to find conductivity or resistivity changes. Using electromagnetics from the air over water, who knows, it something that is a question.

Steve Blasco: But you are also running a multi-spectral scanner with your LARSEN-LIDAR stuff.

Rick Quinn: Well we had good success with that in Lake Huron last year. It gave a good complement to the laser but it is dependent on the blue/green component of the light. You need some clear water to use it effectively. You need the blue/green backscatter to tie on to. Where it does shine is in an environmental approach where you are looking at pollution plumes. It will give you values of sediment content in the water column through the near-surface water.

Bill Scott: Sure but what comes out of it is the water plus a bottom layer. That is one of the things they have. They don't offer it necessarily but they do have the bottom resistivity. It is just a bulk number but certainly if you were flying over a granular area that would be a larger number than if you were in a clay area. That is part of your digital file isn't it George? Or don't you even record it?

George Eaton: No. It will probably not even be recorded.

Bill Scott: Why not consider recording it because right there, you could contour bottom resistivities and that would be a significant advantage in an area that wasn't well known.

I speak as a geophysicist. There are so many imponderables that I would be astounded if we have acoustic precision. On the other hand because different bottoms alter the depth you get, unless you can model that, you cannot be accurate with the bathymetry. I would be interested to see it from that point of view because it would indeed be a way of getting a first estimate of the bottom resistivity.

2.7 Positioning

Neil MacLeod: Dave Thompson, hydrographic and positioning are your part of the business. Do you have some suggestions for more work on any of these issues?

Dave Thompson: Well GPS is the big thing that our industry does. It is affected by things like bathymetry equipment, swath systems and Lidar. Those things are progressing quite rapidly and before we see any sizeable amount of work in the Beaufort Sea, I think those systems will develop substantially to support what you guys do. That should make it a lot easier than has been in the past.

One big problem I see is focusing on all of the data you now have. That to me is the big challenge. Like you say, some of it already has been shredded and lost.

Steve Blasco: A couple of logistics questions, for Dave. If we were considering running an off-shore program in the central Beaufort, can you get by with using differential GPS? Do you need just one reference station on-shore?

Dave Thompson: I would think so. You need a reference station, at the airport or handy to the airport where it is easily supported. You could probably even do one in Inuvik.

John Lewis: Radio communications through Beaufort tends to get little goofy at times.

Dave Thompson: It's hard, yeah. It is not a good area for propagation of HF stuff, but you can still do it. An HF system seems to be the best for that sort of thing.

John Lewis: Well, with the HF system on the Nahidik you can't even talk to Polar Shelf in Tuktoyaktuk from the Yukon Shelf area which is not that far away.

Steve Blasco: You would probably have to use one of the DEW line sites then as a reference point. Say Komakuk or Stokes Point or somewhere like that wouldn't you?

Dave Thompson: Something with an airstrip. Something that is easy to support with a fixed wing aircraft.

George Eaton: What sort of accuracy do you need in real time? I think the best you could get would be 10 m.

John Lewis: Yes, I think 10 m is OK.

George Eaton: Do you want to post-process the stuff or do you want know in real time?

John Lewis: I think you want to know in real time because you want to be able to run adjacent lines with, say, 50 m line spacing.

Rita Olthof: The more receivers you have, the more accurate you can get your position. Is that how it works? Or is that a different system? I know Parks Canada uses a system like that to determine positions. They need at least two receivers, but if they have more they can narrow it down.

Dave Thompson: The statistics might bring it down but not significantly.

Steve Blasco: GPS is important to us because it allows us for the first time to actually operate independently of industry. Over the years, all our work has been tied into the navigation network of the operators or Hydrographic. If there was no network, we didn't have a program. Now we can operate where we want to with a differential GPS system.

John Lewis: A differential GPS system has to be linked via radio or satellite or something out to your vessel. The communications problem in the Beaufort with the HF transmissions through there is it fairly crucial. I believe you have to have a continuous link.

Dave Thompson: If you are going to deal within 5 m, it has to be continuous.

John Lewis: The radio link can be through another communication satellite or through an HF or an SSB or whatever. It has to be kind of a modem link where this data is being transferred back up to the ship all the time. My concern is that HF is not very reliable in the Beaufort.

George Eaton: HF is a problem in the Beaufort, always has been. If a number of people were working up there, another thing would be to campaign with the Coast Guard to get one of their 2 - 400 kilohertz low frequency radios, like on every other coast in the world. Get them to modulate one of those with GPS.

Dave Thompson: Theoretically, you can punch data through where you can't get voice. But there isn't a system operating right now.

Steve Blasco: But there has been in the past? You know of any, George?

George Eaton: Well we have done it with the Lidar airplane.

Rick Quinn: Yeah, we had it in Dolphin and Union Strait.

Dave Thompson: If you are travelling all over the Beaufort you don't necessarily need real time positioning all the time either. If you look at it like that it is a luxury. If you are just going to shoot some regional lines or something, well post-process it later.

Steve Blasco: Still most of our problem comes in when we go over and take on a regional line which we want to go through 2 boreholes. That is a constraint and we don't like to be off more than a few metres.

John Lewis: Often we want to go over glory holes which we have those mapped with side scan and you go over them and confirm that everything is working.

2.8 Data Management

2.8.1 Data Base Systems

Neil MacLeod: John, in your presentation yesterday, you gave us some ideas of what could be done with your firm's software. Where else should we be looking, or how else should we be applying these concepts? What does GIS mean to Beaufort Sea workers?

John Peters: Well, we have always had the best success in building these sorts of applications when the client has been able to define very clearly what they want to see, how they would like to use the system and what problems they would like to solve with it. Before answering your question, it would be nice to briefly discuss how people perceive getting the best advantage out of a data entering system that has an inventory such as this is.

Steve Blasco: One of the things that seems to be coming out is that there are two elements of our system: one is the borehole and geophysical data base itself and the other is the tools for manipulation of the data base and even working with it in a mapping sense. Is it true that you are now putting a union together between the ESEBase data base and the InFocus mapping set up?

John Peters: What you will have shortly is a geotechnical logging capability, a mapping capability and a general data base management capability all rolled into one. You know, it really doesn't matter whether it is ESEBase or that it is InFocus.

Steve Blasco: Call it ESEFocus. Will I be able to call upon ESEFocus to produce a section that goes from the northwest to the southeast across Issigak that will include both the seismic section and 27 boreholes in that zone? I'm sure the borehole information will come out but will I get a seismic section superimposed or a line drawing? I know it is not the interpretive section superimposed. How close are we to something like that?

John Peters: At this stage, we haven't a section capability from the seismic point of view. There is a section capability from a borehole point of view.

John Lewis: There has to be a mandate saying you want to get to that level. At the moment, you are putting interpretive maps and data sets into the system but I don't think anyone has thoughts of trying to put in all the seismic data in profile sections.

Neil MacLeod: It is a large problem to handle. All you could practically do is go along each seismic section and pick every tenth shot point and put in typical section or something, based on somebody's interpretation. Even that would be a huge task.

Steve Blasco: Well that is definitely where we want to go. I know what happened when we tried to do it. We experimented two years ago with some data from the pipeline area. We spent a lot of time. One line was 700 kilobytes of data and it was not that big a line.

Bill Scott: It would be much trickier, however, to produce a section on an arbitrary profile line because that will mean interpolation from lines that were not necessarily parallel to the direction you are asking for.

Steve Blasco: But he is asking me what ultimately we may want. That is where I'm heading.

John Peters: Alright now, I have another question that relates to the seismic track line information. We have put in all of the regional information, plus quite a lot of site survey track data. Is there any reason why we should continue to build it up at the level of the site surveys? I mean, we have already a study catalogue which essentially provides you an outline with the position of the site survey but no track information.

Bob Gowan: You get the number of lines and the spacings of it.

John Peters: Yeah. Exactly. It tells you the statistics on the site but it doesn't actually show the layout. Is there any reason why you would want to continue to build the actual layout of the tracks? Given that it is not a navigation data base.

Neil MacLeod: Probably for 95% of the sites there is no justification for it. But if you are talking about Amauligak, there probably is a need because that is likely where some development will occur.

John Lewis: It also comes back to the question of how much of that data can be found. There is certainly no point in putting in any lines if the data has already been shredded.

Neil MacLeod: I disagree. I think you should show where it is or where it was because some day somebody may come along with a copy of the records. You should code it in such a way that when you call up you can tell that it is a missing line.

Steve Blasco: We have come full cycle now. We are back to the very first thing you started with: the priority is to QC the data bases that exist. Those missing track lines need to be identified and the rest should be all earmarked to tell where the data is.

2.8.2 G.I.S. Applications

John Peters: Where I was leading to with that question was what other sort of data do you want in the system. When you are planning activities in the Beaufort, are you satisfied having seismic coverage and borehole coverage and a few geological maps or do you also want logistical information? Do you want interpretative maps of ice conditions on a seasonal or yearly basis? Do you want transportation stuff, port facilities and these sorts of things? I mean all these additional layers of information are just an extension of what we have now.

Steve Blasco: Now that is where it gets sticky, because the ice people already have that. It is all on MacGraphics with Dickens and Associates. Now our question is how do we import all of that which exists on a digital atlas for ice in a MacIntosh environment into your ESEFocus environment so you can do the things we want.

John Peters: That is not your problem. What you have to say to the programmer is this is what I want. If I'm operating up there, I will need more than the resource information. I also need all of this other environmental or logistical stuff. Go out and get it for me. Then the programmer has the problem of overcoming the technical aspect.

Steve Blasco: What you are saying, John, is you are not technologically limited any more. You are resource limited. It is just a matter of having sufficient money to do the tasks. The software and hardware technology are there to make it work.

John Peters: Yeah. I'm against the notion of populating the data base management system with a whole bunch of data without having some focus on how it will be used at the end of the day.

Bob Gowan: But certainly from a planning point of view, if you are working in the Beaufort, you have to have some kind of a line on where the ice is.

Kevin Hewitt: We have a system that could be used for ice management or whatever.

John Peters: If you were going up there next year to start doing stuff, would you use this very tidy granular data base?

Kevin Hewitt: Well, let's face it, whatever is done in the next year or two should not be driven by operators' needs because we don't have any. We don't have to find gravel right now. But if you want a typical problem, it would be to find out what exists along a pipeline profile and have a cross section for that. I see that as being the most logical use of your program.

Program development for this type of application should not necessarily be funded with granular resource money. The same applies to correlating ice scour with soil strengths, etc. It should not to be funded with NOGAP's granular resource money.

Neil MacLeod: Kevin, how would industry use a granular resource data base?

Kevin Hewitt: The most likely scenario for any work is around the Gulf discovery, Amauligak. We have a unit that can sit in 23 m of water, beyond that we need to build a sub-base for it. Therefore, we are likely to require some site preparation and the use of some granular materials. The last time we did that was in 1983. So we would have to re-evaluate where to get those materials from to make sure that we get the base quality that we need. We will be potentially using this data base.

John Peters: O.K. That is good. That is what we wanted to hear.

Kevin Hewitt: We have our own group that has data on ice and the likelihood of open water in any location in any one year. I don't know what system they use but we don't need another one like it that is built into a granular resources GIS.

John Peters: From an overall planning point of view it is quite nice to consolidate all the different sources of data which will be used to make planning decisions. If you have a system which has the potential for bringing that in or summarizing information in comparison with other aspects, your planning may be very easy. That is the point I'm getting at. I'm sort of opening up the possibility here. Is there any sense in trying to identify data sets in addition to the ones we already have that would make sense for planning purposes?

I look at things like lease information both the exploration leases and dredge site leases, having those in a graphical form overlaid on your other information would be quite useful I would think. And to be able to actually access this status of your dredging leases whether they have expired and that sort of stuff.

Kevin Hewitt: They are all nice things to have but they are not cost effective things to do right now. When you get down to it, there is a lot of critical data that we don't have available to us to make those decisions. For example, where we place our unit is very dependent on the micro-bathymetry at that site. We don't have that information.

Neil MacLeod: There is a factor of scale here too. Think of all the data that exists for the Beaufort Sea. It is a huge area. When someone actually gets down to looking at developing that island structure, the site is very small and you need a lot of very specific information. All that background information is just background information. When you get to detailed engineering, you have to have site-specific information. But it is like a geological map, you just can't plan it for every end user. When you put the geological map together you don't know who will use it or for what purpose.

Bill Scott: The message is you guess what they want, but you would better be right.

Neil MacLeod: The answer is to incorporate the different layers of data as they are available and as people identify a need. You may look at it now and think there is no justification for including the ice data, but ten years from now perhaps ship transportation becomes the mode of removing oil from the Beaufort. Then someone will say we better put that in and they may be willing to pay for it.

John Lewis: But you put it in ten years from now. You don't put it in now.

Rita Olthof: And hopefully they haven't shredded it by then.

2.8.3 Bathymetric Data

John Peters: One of the items missing from the resource data base is bathymetry, at least on the small scale. Is this something we should look at putting together?

Steve Blasco: It is something that we are definitely using. We have a detailed bathymetry map on a one metre interval for the Beaufort on ArcInfo files. All our ice scour information is categorized on a per kilometre per one metre incremental water depth. We didn't develop it but we use it.

John Lewis: Was it developed from the most recent data available?

Steve Blasco: No. It used a Resource Series Map because we have agreed the Natural Resource Series is the basic map we will use for all work. That way everything has a standard base. We have actually digitized that map series.

John Lewis: For the Erksak area, we digitized the 1986 bathymetric data set. That produced a significantly different physiographic interpretation of the seabed. The newer data set has a higher line density and provides a lot more detail.

Steve Blasco: That is true. It is a real conundrum as to when do you transfer to a new datums. So that we could all talk the same language, the three operators and ourselves agreed to all use the Natural Resource Series base until Hydrographic came up with a new one.

John Lewis: CHS, typically doesn't go in and do a one metre contour map of the site area except for navigation. Will they change that?

George Eaton: No. Not unless there is a specific question or request. Then we might do it.

Steve Blasco: Again, it is a question of what basis to use. Bathymetry is a key issue. But then what do you use as the base. Right now we are using the Natural Resource Series because it is one that everyone can access. In fact, there are lots of problems with it.

Bob Gowan: But you have interpreted that, though.

Steve Blasco: Canadian Seabed Research took the 2 m Resource Series Map and interpreted it to 1 m and sent it on to us. I don't think it is really that big a task to actually digitize it.

George Eaton: I think you would look at four or five thousand bucks a chart to do that.

John Peters: I take it that bathymetry is a priority?

Steve Blasco: I would say so because it is really the basis for everything we do.

2.8.4 Computer Generated Cross-Sections

Neil MacLeod: What I think John Peters was asking initially was, what kind of applications do you see for the system. It is a generic question. "How do you think you will use the data or the program?" By "you", I mean Steve, Bob, Kevin, anyone else. Where do you see that you will use the data? What are your problems today that should drive the way the system is put together.

Steve Blasco: Well, ten years ago I pretty well knew in my mind who had what seismic data and the hundred boreholes that were in the system. If somebody asked me about the geology between the middle of the Kringalik Plateau on the 50 m contour over to Kaglulik, I could put that together. I would get the seismic line. I could get the two boreholes and I could compile them. It was quite straight-forward. Now, I can't do that, because there are 2800 boreholes and, god knows, 20000 km of seismic data.

In the long term, I really would like to be able to go to the data base and answer that question. What I want is a section. Hypothetically, I have all the seismic lines in there, so it should be able to give me a seismic section. Now please superimpose on that any borehole that comes within 50 m on either side of that line, plus any in situ tests. Unless we have the data base, it will be impossible to do because:

a) at least the data will be in there and it won't be lost, and

b) there is no way I can remember that there are 42 boreholes which straddled that line.

The next question is whether there is one metre of clay or half a metre? The questions are much more sophisticated now. In the future, the sections we have to produce will be much more detailed.

We have been experimenting on that a bit. Actually we used the Gulf pipeline because it was a big application of SuperTech. We superimposed everything we knew on that line. It demonstrated to me that technology isn't the limitation. It is just a matter of how to compress our data to make it work. It is driven by two things: the need for more detailed information and an inability of our minds to retain or cope with the amount of information that is available. Plus the new one we have added here: stuff disappears with time. But if it is on somebody's disk and Rita is still around, we will have it all. That is what drives us.

John Peters: Would there be support for building a section creating capability?

Steve Blasco: There would be support for that. I would say if we were on a five year program to produce from Amauligak or Isserk the resources would be there to create that. Right now, I think it will be much slower, because the resources are not available. So how do we work at it bit by bit? When we get to the stage where production is approved we don't want to be scrambling like we were ten years ago.

John Peters: Well right now, the query would be to give us all the data in a corridor. We can do that for you, immediately. At that point you take over and you start adding in more data.

John Lewis: You can develop the technique for pulling that section out with the data set you have now. Once you have that, it becomes a question of the effort to put together this humongous data base that is out there at the level of detail that you need to extract any chosen section line.

John Peters: When you said humongous data base, you are talking about the seismic data?

Steve Blasco: Yes and there are smaller data bases like radiocarbon dates which we talked about this morning. There are about 23 or 24 of them at Tarsiut and maybe there are a total of 60 in the Beaufort Sea or even other kinds of data, such as thermal luminescence dates. If you asked me to lay my hands on them, I couldn't do that. I know that we have a variety of reports and I know where I would go to start looking. I think it would take a month of somebody's time to find it all. It would be interesting to have that in the Beaufort data base. There are some things we can do that are manageable and not costly on the computer side. But it sure is costly in terms of someone's time to find the data.

Bob Gowan: Steve, you said earlier that you were not putting any requirements on a GIS system for maps that you are creating yourself. Are you requiring now that they be produced with a digital copy?

Steve Blasco: No. We haven't put any money into developing GIS. The reason for that is, if I tried to take GSC money out of my shop right now to develop GIS there would be disagreement about which system to use.

Bob Gowan: But do you require your contractors to provide a digital copy of data that they are using to produce a map as well as a report or paper copies of the map?

Steve Blasco: I cannot ask a contractor to give me a digital map if it is something he has totally paid for. But, for example, I paid for the scour data base so, I will get a print-out of it and I will get a floppy disk of it too.

Bob Gowan: So eventually will things like maps of seabed sediments or something like that will become available throughout the whole Beaufort.

Steve Blasco: We have a series of eight maps that are all done by hand and the first one is the geotechnical zonation or the physiographic regions. They exist as a series of 1:250,000 maps which were prepared in 1986. They are available for anybody who wants to digitize them for me. I have a project coming up and the digitizing might fit in when we do it. I have been reluctant to digitize some of them because we are actually trying to get them updated.

John Lewis: They can be scanned and converted?

Rick Quinn: Yes but the maps are interpretations of some original data. You still have to input the data, I would think. Your map might change down the road with some new data.

Steve Blasco: You are right. But, in fact, consider the enormous volume of data we have; more so with seismic lines. When we started working with SuperTech, they digitized everything. The next thing you know, we have filled up every disk in the neighbourhood and we haven't even started manipulating it. So we only put in interpreted information. Ultimately, you have to have the data base in there that you use to create the map, but I haven't the resources to do that now.

Bob Gowan: It is the same approach that you use for the SPANS system to classify point data or something like that to overlay on other information to make interpretative maps. They need that system to do that type of function. There is no reason that you can't use the map as one layer in the system. That is a snapshot of one time. It may be updated, but if it is the best we have right now, then that is what I want to use.

Neil MacLeod: Maybe the answer is to have the facilities within the data base management system to incorporate the seismic data in an interpreted form. You need to identify that there are seismic lines crossing or near to the section you want to interpret and you need to be able to bring in the portions of those lines that are in the window that you have identified for your section. The next step is to provide an interpretation of the seismic line where it crosses the section or at one or more points along a line that is adjacent to your section. Then there may be some extrapolation to correct for the fact that the seismic line is not directly on the section that you are trying to interpret.

Interpreting geology from a seismic section is a very judgemental process. Even skilled interpreters need to incorporate much more than a short section of records to make an interpretation. I think the problem of interpreting geology from seismic is bigger than the problem of importing an interpreted section or shot point into the data base from which your section can be drawn. These problems need to be looked at separately. First, we need an ability to draw sections from the data base. Second, we need to create an ability or doorway to bring interpreted shot points from another source into the data base. Third, the software must be developed to interpret short sections of seismic data.

At this time, you couldn't put all the seismic data in a data base. But with another generation of data storage modules or cubes or whatever it may be, perhaps it will become feasible. The same applies to some of George Eaton's stuff. Right now, you couldn't justify putting in every data point CHS has in the Beaufort Sea. But you should put in the interfaces that would allow you to take a disk of digitized bathymetric data for a particular area and use at the time that you are working in that area.

John Peters: Yes and that is quite a simple process, because you have the track line which has an ID and then you have your data which has the same ID so it is just a relational linkage. So you can have a seismic data display or profile display system which can be initiated through plugging onto the actual tracking, today. The package with ESEBase works with exactly the same principle.

Steve Blasco: My strategy for the next couple of years would be to put together a Beaufort Shelf Atlas. There are key seismic lines that are probably the best we will have for some time. In the central geology report, which we are putting together now, there are half a dozen key cross-sections. I would take and digitize only those. Over the next couple of years I would do that for each area. Slowly over time more sections would be added just like we have with the pipeline. That is my strategy.

John Lewis: You have that for the Central Beaufort. You have seven or eight of them.

Steve Blasco: That's right and that is the way I intend to work it for now. I think there are big strides coming up in technology in terms of data compression that will allow us to work with the data in ways we can't now. We are seeing some of it happening now.

2.8.5 Material Gradation

Bob Gowan: An issue that Brian Rogers brought up yesterday, is that most of our studies have only really considered stratigraphy rather than details such as better or poorer qualities of materials or gradation.

John Lewis: We can do that to some extent in the areas where there is significant borehole control, but in other areas all we have to work with is this seismo-stratigraphy so we can't do anything about that. We tried to do it for Isserk in the central proven zone. You know that is where I had the twelve zones with different dredgability codes. But for Erksak, it was a bit of a guess. There was just one hole for control and then the next hole might be 5 km away.

Neil MacLeod: I interpreted Brian Rogers to ask if we can regionally identify the average D50. Can we interpret the limit for exploration on the basis of regional trends in gradation?

John Lewis: That is something we should be able to work out with the data base and with GIS. Go in and dig that out and plot it out, anything with the D50 greater than whatever.

Neil MacLeod: I doubt we have enough data to do that with any confidence.

Steve Blasco: We have a huge report on that and that is where we got the trends. But you are right. There just isn't enough data to push it very far.

John Lewis: Rita was talking about having 2800 samples or boreholes.

Steve Blasco: If you want to see what is happening in Unit C, then you need 50 boreholes that go from the Tuktoyaktuk Peninsula across Tingmiark Plain down to 50 m. We don't have them. We already know there is a trend; it gets finer off-shore. But if you want to know the D50 at exactly 35 m of water, we couldn't say. It is a good concept, we will just have to keep adding more boreholes.

2.9 <u>Environmental Impact</u>

John Peters: What is the climate for environmental impact regulations?

Steve Blasco: At one time, Fisheries and Oceans and Environment Canada became very concerned about dredging on the sea floor. We believe that the dredging process is far less environmentally significant than is ice scouring. You know, in a 100 years, 90% of the sea floor in much of the Beaufort is torn up by ice scour. In comparison, dredging is a very localized operation and the disturbance on the sea floor caused by dredging is considerably less than what is done by nature itself.

A greater concern which was never dealt with is that there may be only a certain number of gravel niches in the Beaufort. If you go suck them all up, the little critters that like to live on gravel niches will not be too impressed. But you are not actually doing that by the relatively small volume of material that they will be moving. The biggest concern was whether the dredging itself was causing an environmental impact. All the critters on the bottom have to get out of the way of the ice keel and getting out of the way of a suction head is not much different.

Kevin Hewitt: When Dome was dredging, we did our own environmental assessment of the borrow site prior to and after dredging. No one came after us and put pressure on us to do it. But I'm sure there would be that pressure now.

3.0 Priorities for Future Work

3.1 Introduction

Neil MacLeod: This is where we want to start looking at targets and defining specific goals for future work. Maybe before we talk about priorities we should consider how fast we should be working in the Beaufort Sea. The operators don't seem to be interested any more. No boreholes have been drilled up there in the last two or three years. Gulf is gone and ESSO has pulled out. The way you have to read it is, we are at least five years from any serious work in the Beaufort and probably longer than that. Chevron is the only major operator to show any new interest of development up there and they are tied up with Hibernia. Until Hibernia is built, they are not likely to get serious about anything in the Canadian Beaufort, unless they find a real hot prospect. Perhaps if Shell was successful with its on-shore stuff and started talking seriously about the infrastructure to tie the delta back to the Norman Wells Oil pipeline things might occur sooner.

Bill Scott: If that happened, there would be a lot of pressure to find gravel along the delta channels.

Steve Blasco: It will be interesting to see what happens with the off-shore. It is still the best area in North America where a major oil company with its big infrastructure might make a profit.

The other interesting thing is that NEB will be releasing more lease blocks. They only released the one block in the recent off-shore bidding, thinking there would be no bids at all, on either the on-shore or the off-shore.

Both ESSO and Gulf have made it known to the federal government that they have financial problems but if they were on a sound footing they would not leave the frontier. Both companies have made it plain that it is their financial woes that has caused them to withdraw from the Beaufort.

Bob Gowan: The question really is what should be the priority of the Beaufort relative to the priority of Mackenzie Valley in terms of spending money on research and for granular resources.

Steve Blasco: The bottom line is that there will not be development in the off-shore until the on-shore is developed. The Delta will go ahead of the off-shore. It has to, unless there is a find comparable to Amauligak that is on the other side of the fault. But I would still bet you that some phased development will pick up something in the Delta before the off-shore.

Bill Scott: The fact is there won't be a huge find in the Beaufort right now because nobody is actually doing enough.

Steve Blasco: Although nobody is drilling, there are a lot of seismic things to do.

John Lewis: Also, there are new commitments by Amoco and by Chevron from the latest lease sales. There will be something going on in the Beaufort and it will probably be more seismic work.

Steve Blasco: Some of it will be for engineering. They want to get their price of production down and they can't do it without some engineering. I think that is the purpose of Amoco's new R & D committee. How do you get the price of oil transportation and productions costs down? You have to do some research.

Neil MacLeod: If there is a future for the Beaufort, significant operations are not likely for the next three or four years. The time frame is probably four to twelve years.

John Lewis: Certainly that is the kind of time frame for production. I would think that some exploration activities will be still going on even though on a small scale.

Steve Blasco: In the meantime, we will try to pick up on the geophysical stuff and when the operators put a coring vessel in the Beaufort, to do a couple of sites, we will take advantage of it and add on to the program for the borehole information we need.

3.2 Operator's Priorities

Neil MacLeod: Kevin, as the only industry representative here, what can you tell us about the future of the Beaufort? If it does have one, where should we focus our efforts in the search for granular resources?

Kevin Hewitt: I think you have to consider the importance of the Beaufort from the interest of the operators over the last two days. We know that Gulf is basically out of the picture. After all, they just pulled out of Hibernia. Beaudril is up for sale, or should I say they are looking for someone to manage those assets and although we are in ESSO's building, they don't have anyone here.

From an industry standpoint, what we expect in the next few years, is to drill in the area around Amauligak. We may need to use some granular materials there because the water depth is a little deep for the SSDC mat system without a berm. That is the only project that I see which may require granular materials in the near term.

Secondly, there are no dredges in the Beaufort now. Before anything could happen, it would require a dredge. Therefore, I don't think that we should be looking at an industry project to be driving what we do here. It is my view that we should be trying to fill in gaps in the models that have been identified here and not try to be too site specific.

Bill Scott: I have some questions for Kevin. What is the shallowest you can put an SSDC with a mat? And what is the deepest water for an ice island?

Kevin Hewitt: The SSDC and mat need 7 m to float it in and an ice island, I think, can be used out to about 8 m.

Bill Scott: So in fact there is no need for gravels in general for exploration. But there would be at the time that production came up. Would you consider an SSDC mat set up for production?

Kevin Hewitt: Yes. We are actually looking at that option for a small scale production operation.

Bill Scott: So, in fact with that around, the demand for sand and/or gravel is much diminished over what it used to be.

Kevin Hewitt: It is diminished. But for something around the Kogyuk or Amauligak areas where there are 20 to 30 m of water, we may need several metres of sand or gravel to bring it up to where we can use the SSDC and mat.

Bill Scott: So there is still a reason to talk about granular resources? That is all I was interested in. From the way you were talking yesterday, it seemed as if the demand would be so sharply reduced that maybe there is no need for identifying new areas.

Neil MacLeod: You will get different opinions on that too. Jeff Weaver has suggested that Esso's concepts are for a much reduced need for sand. In fact, they will probably try and design ways around having to use dredges. On the other hand, there are needs for gravel such as for erosion protection for pipelines and structures.

John Lewis: Well ESSO have been getting some flak from the Coast Guard now about having to clean up those artificial islands.

Neil MacLeod: I think that is true for exploration structures, but for long term production facilities, you could justify those clean-up costs. It sounds like ESSO would prefer some alternatives to dredged facilities whether it is a mat or some sort of a conical drilling unit perhaps something like the Molikpaq. They are aiming at minimizing the need for sand and gravel. Obviously if they were sitting some place where there was lots of good sand they might alter their plans. Jeff indicated their first generation concept is based around something in the Amauligak area. They would like to tie Issungnak into that for a local network.

Kevin Hewitt: My personal opinion is that there is still a need for some granular materials. I think that the technology of building off-shore structures has changed dramatically in the last ten years. Hence there has been a change in the need for granular materials. There is still a need but it may be an order of magnitude less than it was once.

We cannot predict the future but a benefit to some of the things we do here is that the technology that is being created for the Arctic off-shore environment is very marketable for Canada to sell into Russia. Most of Russia's oil prospects are in the Arctic and a pretty good portion are in the off-shore.

3.3 Data Archives

John Lewis: I am concerned about all the lost data. When we came out to Calgary in 1988 to collect the data for the central Beaufort area, a fairly large amount of it couldn't be found within a month's searching. I'm sure it is still around somewhere. Dome had a very good data storage system and the people who were there in 1981 knew exactly how to get everything. But in '88 when we came back, we couldn't find it. I recommend that someone should be charged with putting in some serious effort to try and locate as much as possible of this data and get it centralized and organized.

Steve Blasco: We can support that. What he simply means is that somebody in Calgary will have to do it.

Neil MacLeod: In a sense, the data catalogue and geophysical data base identify most of the programs and that is the first step. Someone has to go through that listing and find as many of them as they can. Whether you could find someone now who knows when it was done and what it looks like, is pretty iffy. I went looking for Esso data from Issigak only three years after it was collected. They had hundreds of kilometres of seismic data between Issigak and Tarsiut. It was gone.

Steve Blasco: We know that data was mistakenly shredded because of a screw up when Cathy Nelson left.

John Lewis: Would their tapes still be around somewhere?

Steve Blasco: They may be in a couple of boxes of multi-channel we were given but I don't know because I persisted in trying to figure out where the paper traces had gone.

Neil MacLeod: It seems that a very strong case can be made for an archive for the shallow marine seismic data.

Steve Blasco: There are 3 years of Gulf data missing.

John Lewis: I know the '81 Dome data went missing and I remember specifically boxing all that up, labelling it all very nicely and sending it back.

Steve Blasco: The data collected by Huntec in '74, is still the best data collected north of Richards Island. I would like to get my hands on it but I don't know where it is. It has completely disappeared. It shows all the deformation and internal structure of Unit B and the deformation there was marvellous stuff.

George Eaton: From an outsider's point of view, it sounds like a pretty deplorable condition. Any money you spend trying to get that stuff together now could certainly save you money in the future. The cost of going out and getting it again is just astronomical compared to looking in the basement for 2 or 3 months.

Bob Gowan: This would be the time to do it wouldn't it?

John Lewis: Especially since we should have done it 5 years ago. I recommend some kind of a program where the government or someone becomes a depository for all of this data and organizes a central clearing house or library.

Steve Blasco: We sometimes forget that the National Energy Board has a repository of data as well. It is not quite as complete as industry's, because industry only files what they need to, but we can also find some data through NEB. I believe they have a couple of copies of each site survey. That would be with Laura Richards and her group.

Neil MacLeod: Ray Smith was telling me yesterday they actually have had operators coming to them to find stuff that has been lost.

John Lewis: In '88 we photocopied as much as we could find of the data for the central Beaufort. That all resides at AGC now. That was all done under our projects.

John Peters: This issue of the central repository is critical to the whole Beaufort data base. I think you are just wasting your effort if you leave the data records dispersed.

Steve Blasco: Well GSC has already agreed we would do it. Repetitive mapping with side scan data is really important to us for our ice scour studies. So we are basically the repository for all of that. Our biggest problem is trying to keep track of it. We use it and others use it for something else and it is cycled around a lot. NEB is definitely a possible repository, maybe we should discuss it with them. It may be more appropriate to store the data here in Calgary.

Bill Scott: It has to be a maintained collection. You can't just store it. There is a possibility that a lot of this stuff might be put on microfilm and you actually lend out the microfilm and not the original record.

Steve Blasco: Well, we looked into that some time ago but it would cost a few hundred thousand dollars to microfilm all this data. The question is who pays? The problem is if you raise all those issues now, you would never get to do the first step of data archiving. Another problem is with the ultimate fate of NEB. I suspect a decade from now, you may find that all the northern data is somewhere in Yellowknife and NEB doesn't exist as an organization.

Neil MacLeod: What about ISPG? It is here in Calgary.

Steve Blasco: Well ISPG already defaulted all the Beaufort stuff to us as it is. ISPG is GSC and it could do it, you know. ISPG is here and so are the operators.

John Peters: Within AGC or ISPG there is already person-time and expertise that would be able to maintain a catalogue.

Steve Blasco: That is right. We have a full-time curation staff.

John Lewis: What should also be considered is what formats to use to store it in so it could be accessed.

Rick Quinn: You don't want to re-invent the wheel with all this high-risk type of stuff. They are doing it in deep seismic.

Steve Blasco: I'm sure there are standard procedure. In actual fact, we have exceeded the volume of data collected for deep seismic stuff because our sample rates are so high. You are operating at 2 - 4 milliseconds. We want to save 2 to 4 kilohertz of data and so our data volume is huge.

Rick Quinn: Yes, but, in many cases when you go through the interpretation and you are delineating your reflectors would you digitize the particular horizon?

John Lewis: That is the way SuperTech was developed, the old software.

Rick Quinn: You are talking about a tremendous volume of just the field data. It is sitting in raw form. Then you have the mish-mash of digitized reflectors going on and then you have the final maps.

John Lewis: That aspect becomes very difficult. There were certainly enough paper rolls to more than fill this room. If you could get 50% of them now I think you would be doing very well. It would probably take you a couple of months of data search, chasing things around to find it.

Bill Scott: I think that is being awful optimistic. I think it would take a year. It is not a trivial problem any more to get this stuff. You will have to identify what it is you are looking for, track down who did it, interview them, find out exactly where it was and what was done with it initially and follow the trail of where it has been. All that will take real time and money but it is still cheaper than doing it again.

Steve Blasco: I would look at it from another way. I would simply go to Gulf and ask where do you store all your data. Then we simply go through all of that. That is what will take time.

John Lewis: That may be sort of mind boggling because they may have several warehouses full of boxes. It will all be seismic data. Most of it for deep exploration. They will all look the same and the ones we want won't be well marked.

Bill Scott: Another problem is you get say 6 boxes and they are full of records. When you starting working through them, you figure out it is an area of interest. But you will not find the track plots with it. You will have to go somewhere else to get those.

Steve Blasco: We have that on the data bases that McElhanney and EBA have put together. Most of the stuff we have all worked with and it is stored reasonably well. It is finding it.

Bill Scott: Well, in fact there is more value to keeping the interpretation available than the raw data. As long as the raw data can be found. The interpretation is a value-added effort. Steve was talking about these eight maps. They are worth much more than just the raw data because somebody has given some thought to how they correlate and those correlations are part of the maps. So if you want a product that you will use, it is probably better to take the map on which somebody has already done the correlation and use it to build your thinking. I don't know that we want all the raw data to be part of the data base.

John Lewis: The raw data should be indexed.

Bill Scott: You should know where the raw data is so that if you don't trust a piece of it or if something else comes up you can go check.

Steve Blasco: Now that we have these geophysical data bases I'm not interested in one that shows track plots of data that is lost. I would sooner get those lines off the system because it creates a misunderstanding. I would really support John's recommendation to confirm what we have, where it is and how it is stored. The Geological Survey has offered to be an ultimate repository or NEB if it is to be stored here. Either one can curate it.

John Peters: This data never seems to stay in one place. You can find all the data and take a snapshot today but in a year's time you can't go back and find it.

Bill Scott: We would know that if it is in a repository because then there is a record of where it went and an active curator will chase people after a reasonable length of time.

3.4 Geological Studies

Neil MacLeod: Steve, will you go back through your many bright ideas and clearly identify your goals for geological work in the next short while?

Steve Blasco: I would say in the next phase, we need to collect some additional geophysical data in each of the prospect areas such as Isserk and we need regional data related to Issigak. We should focus on the central region and as a lesser priority on Herschel Island and the Yukon Shelf. I would, in fact, put a little slightly higher priority on establishing the geology of the Kaglulik Plains so we could categorically state it is not an area where we have much hope of finding sand and/or gravel.

Neil MacLeod: There was a fair bit of work done in the Amauligak area which was presented in Scott Dallimore's report. Is there anything which came out of that report that needs to be looked at?

Steve Blasco: We identified one area earlier when we talked about recognition of some possible shorelines and some gravels in the southern Akpak area. It is a key area because it is close to Amauligak.

I do believe this whole question of the on-shore/off-shore geologic correlation should have a high priority, because it is a factor in understanding the geology of all the different prospects. It would be great to geophysically and geologically cover the area from Issigak right across to Amauligak. My next priority would then probably be Kaglulik because it is largely an unknown area.

Bob Gowan: How about Nerlerk?

Steve Blasco: Well, that is further out. We do know that the sand plains that we are drawing on, including Erksak, get finer and finer and more interbated and more distal at the north end of the Tingmiark Plain and Akpak Plateau. On that basis, we can eliminated the Nerlerk area for now. That may or may not be correct.

Neil MacLeod: I think for practical purposes, it is unlikely that anything will be built in deeper water until something is built in shallow water. You must be very optimistic to think that there is not a lot of time to adjust to a deeper water scenario.

John Lewis: At some point there may be some exploration work done in the deeper water. Would they go back to the drill ship technology and summer-only drilling?

Kevin Hewitt: That would be the most cost effective method.

John Lewis: So there would be no real requirement to come up for granular resource out there.

Steve Blasco: One thing that has to come out of our PERD meetings is just what Neil said. The assumption is that development will occur progressively northwards. First they will develop in the Delta and then they will be looking to the near shore and they will slowly work their way off-shore. Maybe Amauligak is the key point, but if they find a big deposit in closer to the shore, then it will become the focus. I would just as soon concentrate our efforts on the near shore and mid-water depths and not spread our efforts too thinly. If we only have a little bit of information in a thousand places, we won't have the information that will make development cost effective.

Neil MacLeod: Steve, are there other aspects of the geology to consider?

Steve Blasco: The Megatransect was a series of five deep boreholes that Terrain Sciences did. They put together the stratigraphy and geology for that transect and it is built into our draft of the central geology report. So any implications that has on the models would directly relate to the granular resource. It suggests that Units D and E and other units underlying Unit C, have continuity with the on-shore and the underlying clay. Unit D appears as the Hooper Clay on-shore. That is a key stratigraphic link.

John Lewis: We are still left with the Toker Point unit.

Steve Blasco: Yes. We are still left with that issue. It has to be sorted out because that unit is a potentially significant source of granular resources.

John Lewis: Well it is also the age aspect of that because if we do push the stratigraphy straight through underneath all that, then that makes the Toker Point tills very young.

Steve Blasco: Well we have talked to people outside Terrain Sciences such as Wayne Pollard, Fred Michel and even more recently Ross Mckay. There is a thought that the Toker Point till is Late Wisconsin in age. That would correlate with our off-shore stratigraphy. We might argue the chronology question for years and I don't know at this point, if it is really solving this problem about granular resources. It is the stratigraphy that is a key to the resource, hopefully chronology will come along. The idea is to use the geology to find more sand and gravel. We can't lose sight of that.

Neil MacLeod: I think you have to solve the chronology question before you can identify the origin of a lot these gravel deposits. We have proven many times there is more sand out there than you can ever use, but there is not enough gravel. If there is a key to finding the gravel, it will be in solving that till sheet problem. My feeling is if someone could resolve that question in a positive way, it could have a very big impact on where you conduct exploration for gravel.

Steve Blasco: There are some other concerns in all this. When you talk to Jean-Serge Vincent about the issue, he says that you may not get enough gravel out of Toker Point till to make gravel deposits. The till is a very clayey deposit. And we also have glacial sequences on Hooper and Pelly Islands. We have no idea where they sit in time.

That brings you right back to where we were a few minutes ago. You have to focus on that triangle that bounds Issigak over to Amauligak and everything south of that right to the shoreline. We are working with Megatransect right now, looking at biostratigraphy to try and tie the two together. The big thing will be actually dating material that both Terrain Sciences and ourselves agree is datable. Then whatever date comes out, we don't argue about.

John Lewis: The area you just outlined is also the area that likely will be most important for finding more gravels. You see, it is all tied together. That is certainly the area where we want to get the most recent bathymetry and update the bathymetry maps and look at them from a detailed geologic point of view. Any kind of little shoal feature that may have been missed on the earlier map sheets could be important.

Neil MacLeod: Steve, if you had abundant funds, how would you go about solving the debate? You are talking a small area needing some critical data.

Steve Blasco: The only way to solve it is to run seismic right from the on-shore to the off-shore to put a seismo-stratigraphy in place, first. Then you run a series of boreholes that are 20 to 50 m deep in a series of lines from the on-shore to the off-shore. Megatransect is one and the other end line would be in the Ikit Trough. It would have to sort out your problem. That is basically where we are headed as resources become available.

In fact, most of our PERD awards will focus in the next few years on the central Beaufort. Which brings another point to mind. It is not just Indian and Northern Affairs NOGAP resources that can be dealt with here. There may be geological resources and PERD resources that can be linked to make this all work better, so we can finally research the resources.

3.5 Evaluation of Equipment

Bill Scott: It would be worth perhaps looking at a 2 week experiment with all of the presently available new technology over 1 or 2 of these areas where there really is good control. That would be a way of examining the potential of new equipment or techniques. I don't think there is any sense in talking about major regional surveys because there isn't a driving economic force.

Guy Fortin: Is there no southern site where we can do a test like that? Perhaps off Halifax harbour. Somewhere with a gravel bed. We can have a number of companies try their system and select the best one before we go up north.

Bill Scott: It is hard to find a wide expanse of shallow water with the same kind of geology. In fact, parts of the B.C. coast around Vancouver Harbour are better. Those areas have comparable features but it is really hard to find an area with the same geology. Or even something close.

Rick Quinn: We discussed many ideas for fine tuning different technologies, resistivities, seismics, line-cone effects, chirp sonars and so on. That is all well and good but the money is pretty tight these days and to go up to the Beaufort Sea and do a lot of things that have never been tried before is expensive. It is cheap to mobilize to the Fraser Delta. It is a deltaic environment, where we can try some of these things and see if you can really run a boomer and a resistivity system together. Maybe you don't have the permafrost and you can always say you don't have this and you don't that, but guys like John who have been in the business long enough, know that if you test some of these systems, either they work in a gross sense or they are totally incompatible. You don't want to be testing those things up in the real shallow water of the Beaufort where you have logistics against you and a tremendous cost. With the Fraser Delta, there may be other money you could tap into because there are other interests in the Delta; like B.C. Hydro, or PGC and Arktos isn't very far away, either.

Steve Blasco: There is a GSC program to study the Fraser Delta underway now. It is being done under Dave Prior. We could consider some advantage of that. One of the things we are doing in that program is to evaluate a shear wave source that Angela Davis will be bringing over from England. She has been working with shear waves for the last ten years and has developed a deep-towed sled. It is to be tested at Hibernia and in Fraser Delta and if that goes well, in two years we will use the shear wave source in the Beaufort to get around shallow gas problems.

Rick Quinn: Well in the Fraser Delta you have more of a season to work in. You can do it in the off season when it is less expensive and you get more time to play around. There is certainly merit in a test program which is dovetailed on to some of the ongoing work in the Fraser Delta.

Steve Blasco: I'm working the same route with Russ Parrott's digital initiative. We have it slated for the Beaufort but definitely we will look at the programs that he is already working on. We don't want to take a system up north that is still temperamental and not operational. It will be tested in the Fraser Delta and east coast before it goes north.

Bill Scott: In that case it would be all worthwhile to look at getting some control for somewhere in the Fraser Delta that would make it a useful test area. There is a certain amount of borehole data there for other reasons. I mean people have done geotechnical investigations so it should be worth trying to compile some of that and find an area where the geology is known where one could do tests.

Neil MacLeod: I take it is not just a matter of picking a site that has data. It is picking a site that is representative of the Beaufort.

Steve Blasco: The counter point of that is we have done a hell of a lot of work in the Beaufort. We have a lot of ground truth in an area that you won't have in the Fraser Delta. You have to make sure you can have something.

Neil MacLeod: So maybe, the broad task for John should be to develop a data base for the Fraser Delta first. From that we will figure out where the right section is.

Bill Scott: It is possible that other money might be available to fund that. I mean that it would be logical thing for the Fraser Delta people to be looking at anyway and maybe that is already underway.

3.6 Data Management Systems

Neil MacLeod: We discussed the applications for the data base programs and GIS earlier. John, will you review the main objectives that came out of that.

John Peters: Well, I will recap on the priorities. We are not looking at the technology issue here; we are looking at data. And, it looks like, as far as I can gather, the main priority will be to provide some Quality Control of the data. That could be quite a substantive task. We have recognized that bathymetry is important. So we should be trying to include the existing bathymetry including the areas where Glen Gilbert has digitized the bathymetry. In order of priority after that, we have radiocarbon dates and there is the set of 1:250,000 geological maps that we may also decide to bring in. I think the main thing is to cycle back to this QC and get the actual inventory straightened out.

Bob Gowan: One of the projects that I had planned and which was caught in the freeze (on government spending) was to look at marrying the existing InFocus system with a Raster based system. Clarke University has developed a real cheap version of a Raster based system that can handle quite a number of problems in terms of correlation of the data between layers and actually overlaying layers, rather than over-plotting as you end up doing with InFocus. It was to be done through a pilot project to try to relate some of these other factors like existing ice cover, existing environmental constraints and that sort of thing as a tool that could be used for planning purposes. It could be used in something as simple as planning a field program when we are working with limited funds and trying to determine physical environmental and operational priorities. That is certainly a candidate for carrying on with future work.

John Peters: It is a very interesting system actually and there is very good potential. You might have heard of it, Bill. Program called "IDRISI". It does a lot of things that a system like SPANS would do. It is a spatial analysis system. It is quite simple to take one cover sheet and overlay it with another one to produce a new map.

John Lewis: This could be an easier way of incorporating the maps that currently exist by scanning them or something in Raster.

John Peters: You would bastardize an existing coverage in some way. I think it has to be a pilot project because there is not enough data to sustain such a thing right now, as a production sort of tool. Blasco's eight maps would be wonderful.

Bob Gowan: It is the type of tool you would use regionally, rather than searching on a point basis, or borehole grid type of basis. You could put in the depth to the granular material, a certain quality level and a certain water depth or whatever and it would only display those various things that met the criteria. So it is an exact overlay where it creates a product from the various layers you are using with it.

Steve Blasco: An addendum to all that is the continued development of computer techniques, GIS and data bases, etc., as the basis on which we work in future. Somehow we have to incorporate that into the resources of a project. When we are doing bathymetry, we don't just do a series of maps but we also put it into the data base. Somehow we have to try and work that way.

I have concern in the long term about having another reference map for the Beaufort and replacing the Natural Resource Series which we are using. Maybe Indian Affairs needs to write a letter to the Hydrographic Survey and say "Look we need a new data base map and we would like an electronic map of the Beaufort and need it for..." Does that carry any impact? We definitely have a need which I don't think will go away.

Bob Gowan: I think we start by approaching CHS about the recent data. That is an immediate requirement. There will be future ones for new base maps.

3.7 Granular Resource Prospects

Neil MacLeod: We have talked about quite a few exploration prospects and keyed on the well explored deposits. During the last couple of days, we have talked about quite a few other areas where we would like to see some work done. I think we have covered them all, now it is just a matter now of bringing them back out to establish priorities. I think the central Beaufort area around Amauligak probably has to be the first priority based on where development is likely to occur. I think there is information that suggests there might be gravel in the Isserk area and that is something we need to explore. What other deposits, prospects can you think of that fit that category now.

Steve Blasco: Well again, someone should look and see if there are other deposits like Issigak in that area. You follow along that contour and back towards Issigak's source. And we should do something in the area to the east of Amauligak, in the Kaglulik plain area, before we go back and further explore Herschel or Yukon. You are trapped between trying to further delineate what is known versus looking at an area we don't anything about it at all. It has to come down to the logistics. Which is the closest area to potential production sites? Banks Island is now a lower priority until you find out that there are no resources elsewhere and we have to go there.

I haven't heard any other new areas come to light. At the north end of the Akpak Plateau, for example, is a huge delta that is in deep water. There are some delta fans that were built out towards the shelf edge, when the sea water level was lower. The fans are much like the alluvial fans that you have on the Yukon Coast.

John Lewis: But again you have to transport the coarse material all away across the shelf before you get it there and I wonder if that is likely.

Steve Blasco: I think it is when you consider where did the sediments go that were in Kugmallit Trough and the Niglit Channels in the Erksak Trough. That stuff is somewhere. Unfortunately it is out beyond 35 m water depth so it may not be practical. I don't know of any other site. Perhaps in the Baillie Island area. Gravel has been reported north of Baillie Island.

Neil MacLeod: We have poked around out there several years ago for Dome and we didn't find anything.

Bill Scott: I think that you can't really make a case for doing anything very far from Amauligak until you have proven that there is no gravel there. It is really interesting to look at all the other places in terms of long term gravel potential. But until you can demonstrate there isn't available gravel around the south end of Akpak Plateau, then there is really no call to go anywhere else. I don't see anybody developing anything off-shore in the next 4 or 5 years except in the Amauligak region right now. Nobody else has anything of obvious production value like Amauligak.

Neil MacLeod: Any suggestions of where you would look first?

Bill Scott: There is a lot of evidence for old strand lines along the west of the Kugmallit Channel and I believe there is coarse gravel in places. We found that some of those sediments had very high resistivities when we were working for ESSO in the Arnak area east of Richards Island. The deposits we were tracing were open ended. It was going off to the northwest and out of the survey area. The old Huntec data had outlined the strand lines and that is why we were looking there initially.

When they built the last Arnak, a lot of the fill was actually gravel. It was the same stuff that we had been mapping with the resistivity. I don't think anybody has ever looked in that area very much.

Neil MacLeod: From the Amauligak development point of view having gravel in that area would be pretty attractive.

Steve Blasco: Yeah. Because the features tend to be linear we think they must have something to do with an old shoreline. It is the only thing we could think of that would generate that kind of linear form. A bar or channels all the other landforms tend to have limited extent and less linear character. The problem with old shorelines is that if the shelf was tilted due to ice loading, the shoreline won't always follow a bathymetric line.

Bill Scott: For a lot of this area, the water depth is only 8 to 9 m. We never tested some of the better areas and I don't think we looked west of the island that was being built. There was certainly some better looking stuff on that side that we never tested.

Neil MacLeod: I recall some interesting features of similar type that are on the west side of the Akpak Plateau. On some of Muharrem's old data there were some pretty nice delta and terrace-type deposits that seemed to be built by streams flowing off the Akpak into the Ikit Trough.

3.8 Re-Interpreting Bathymetry

John Lewis: I suggest that we take the newest version of the CHS data and re-contour it to re-assess those areas. I can see a project developed to identify geologic features from detailed bathymetric maps. We should look at those details to outline new targets.

Steve Blasco: That would be a first step.

John Lewis: You might consider some detailed interpretation on the newest bathymetry for Issigak and Isserk regions. When we were doing the Erksak area, we managed to get the newer hydrographic survey data and contour it. An awful lot of small shoal features showed up through the Erksak area. I think there was a considerable amount of newer hydrographic survey done on the shelf area certainly a lot of the areas were outside the Erksak region. No one has pulled out the work sheets and re-contoured them at a one metre contour interval or as small as you possibly can with a geologic framework in mind. It might be worth some effort to do that on a broader basis.

George Eaton: Go ahead and request the data. It is an obvious thing that is an obstacle. It has been in the past. This stuff should be
presentable in digital form. The original soundings are at 100 m line spacing but the final sheets we have on record are reduced to 100,000 scale with 500 m line spacing. But the raw stuff is around.

John Lewis: Yeah, but what we want is the work sheets which are 20,000 or 30,000 scale maps.

George Eaton: Yeah, anything since '85 there shouldn't be any great difficult in getting that out.

John Lewis: I think it is worth the effort on looking at most of the Beaufort shelf with the newer data set where you do have the higher volume density of 100 and 200 m line spacings and things like that. From this point of view and I think you may find an awful lot of features similar to Issigak. Things will start popping up at you.

Steve Blasco: Is there any way that some of the things that are of interest can be added on to the next Canadian Hydrographic Service program or is your program fixed.

George Eaton: If you have a request certainly make it known to Tony O'Connor.

3.9 Summary of Priorities

Neil MacLeod: It seems the first off-shore development work will be around Amauligak. That is something that has come out a dozen times today. Gravel deposits near Amauligak must be the first priority. From a technology point of view, Steve, you made some comments on different systems and how they might be used. Rick, I like your idea for taking stuff out to the west coast and doing some trials in reasonable conditions before we hit the big expenses of mobilizing to the Beaufort are quite valid. That is where some of the equipment will fall by the way.

The major recommendations that have been made today are summarized in the next section of this report.

Steve Blasco: The other thing that should drive our priorities is opportunity based options. If something is going on in the Beaufort, we should piggyback on it to maximize the impact to granular resource. We have our priorities from A to Z, but in actual fact, we do them when the opportunity presents itself. When a coring vessel is there or a seismic vessel, we do what we can. We may have a survey vessel next year. It will be there and probably for the last time. Because we won't have to pay huge ship costs, we will do a geophysical survey next year. Thereafter we will have hellishly large ship costs.

3.10 Closing

Neil MacLeod: Well we have come to the time when we must think about wrapping this up. We covered the issues, we covered the issues again and talked about them again. I appreciate everyone's comments. I think it has been a very successful workshop meeting. I hope you all agree. It has been fun to get together with good old friends and to compare ideas.

We owe ESSO a vote of thanks for these facilities and their help. We have not suffered in these accommodations by any means. I would also like to thank Bob for sponsoring us and encouraging us. I hope when the final reports are put together, we have provided him with the information that he is after. Thank you Bob. Thank you gentlemen and Rita. That is it.

4.0 Editor's Summary of Recommendations

4.1 NOGAP Study Areas

4.1.1 Yukon Shelf

- Sampling of the prospects identified in the NOGAP study is needed to confirm interpretations of thickness.

- Most of the data available for this area was not collected for granular resource exploration. Therefore, geophysical work with more appropriate tools might help to improve the understanding of the granular deposits.

- Additional exploration should focus on the area of mega-ripples along the edge of the Shelf at the Mackenzie Trough and in the shallow to mid-depth water range.

4.1.2 Herschel Island

- There are several areas along the coast where gravel is suspected but which have not been explored.

- The thickness of most deposits in this area has not been determined. Some boreholes or resistivity might be considered.

- Gulf collected some seabed data when looking for set down areas for the Molikpaq. These have not been reviewed for evidence of granular deposits or their geological value.

4.1.3 Issigak

- The stratigraphic link between Issigak and Tarsiut should be confirmed because it is fundamental to the interpretation of age.

- The morphology of Issigak should be tested by on site examination.

- The results of that examination should be used to direct further investigation of either an upstream source (fluvial model) or bathometrically similar deposit (strand line model).

- The Arktos set-up might be appropriate for exploring in the shallow water between Issigak and Pelly Island.

- Steve Blasco may have a couple of boxes containing multi-channel data from ESSO's lost data set for the area between Issigak and Tarsiut. This data should be reviewed to confirm or revise thelocal geologic model.

- Bathymetric work sheets at CHS may provide details of local relief that indicate similar deposits or help to interpret the origin of the deposit.

4.1.4 Isserk

- Delineation of granular resources has been hampered by a thin upper sand layer which seismically obscures a lower sand which includes some gravel rich facies. New seismic methods, including heave compensation or resistivity methods could be used to improve our understanding of the deposit.

- Borehole control is needed in the southwest corner of the block.

- More exploration is needed on the tail of the deposit which extends to the southeast outside the block.

- Detailed look at CHS bathymetric work sheets may provide new exploration prospects in the area.

4.1.5 Erksak

Borehole control for seismic interpretation is incomplete. Good prospects have been identified in Erksak Channel and along the edge of Kugmallit Channel, but these need borehole confirmation.

4.1.6 Banks Island

- Dredging in this area will comprise selective development of small pockets of till in rock. The use of correlation curves based on a few boreholes to help interpret seismic data would simplify the exploration process.

- Accurate bathymetric mapping is needed for navigation of dredges and would help to identify pockets of till.

4.1.7 Amauligak Area

- This should be the focal point of granular resource exploration during next few years. More distant potential sources should be de-emphasized.

- Gravel prospects near the Amauligak area are much more valuable than sand prospects.

4.1.8 Arnak/Akpak

Old strand line features identified in the Arnak area should be delineated and evaluated. There is evidence of gravel in these.

4.2 Geological Objectives (for Granular Resource Application)

- The stratigraphic schism between on-shore and off-shore has resulted in geological models that may be overlooking gravel deposits. Detailed work on the area between Amauligak, Issigak and Richards Island is needed to resolve.

- The geo-chronology and the marine limit of Toker Point tills is disputed by many. Mapping and dating to confirm or modify the models are needed.

- The gradational character and variation of Toker Point till should be assessed for its potential as a source of granular materials after re-working. Perhaps it is too fine grained to worry about.

- Similarly, the geologic and gradational character of tills on Hooper Island and Pelly Island need to be correlated with Toker Point eposits and possible granular deposits.

- The geological models suggest the first priority for granular resources exploration should be in the Amauligak/Issigak/North Head triangle. The second priority is the Kaglulik Plain, including Erksak, if only to prove there is not any viable sources out there. The third priority is the Yukon/Herschel area.

4.3 Data Archives

- A thorough search for seismic records of shallow marine deposits should be undertaken to retrieve valuable data, identify lost and destroyed records and establish an archive.

- The database of geophysical track plots should be modified to show lost, destroyed, archived, good, bad, etc., quality assessment information.

- A government agency should be selected to archive all marine seismic data. The Atlantic Geoscience Centre, National Energy Board and Institute of Sedimentary and Petroleum Geology were suggested as acceptable curators.

4.4 Data Base/G.I.S.

- Engineering and geological applications of borehole data base require capabilities to generate cross-section incorporating borehole data. Some facilities to incorporate seismic data into the section will be needed in the long term.

- Methods of incorporating seismic data into cross-sections generated by the data base should be developed in stages.

- NOGAP funding should not be used for developing cross-section generating capabilities. Perhaps PERD and GSC money should be used.

- GIS development incorporating data available in other specialty data bases should proceed slowly, as required at present.

- GIS should incorporate bathymetric base maps, modified bathymetric data (CSR's data) and the facility to input new digital data from CHS.

- GIS should incorporate radio carbon dates and 1:250,000 geological maps.

- NOGAP funding should be reserved for GIS development relating directly to granular resource applications. It should not be used for engineering, geological, logistical or infrastructure input.

4.5 New Technology

- The concept of a towed video system that is able to contour fly over the bottom was advanced to study/document bottom features such as boulders, ripples and gravel deposits.

- The need to develop and incorporate heave compensation on seismic equipment systems was raised many times.

- The incorporation of GPS techniques for navigation and heave compensation post-processing was identified as a significant technological advance.

- The Coast Guard should be asked to provide low frequency modulated radio beacons for GPS applications in the Beaufort.

- Resistivity techniques offer the ability to see into and through granular deposits which seismic methods cannot do. Continued development of resistivity should be promoted and complementary seismic/resistivity programs should be tried.

- Seabed sediments and pore water should be routinely sampled and tested for resistivity and salinity to establish an atlas of resistivity calibration data for the Beaufort.

- Research of sonar/bathymetric data already collected should be conducted to assess whether that data can provide an indication of seabed resistivities hence sediment type on a first approximation basis. Further CHS bathymetric work should be modified to record seabed resistivity data for this purpose.

- The use of resistivity from the ice (winter program) is a feasible method of investigating bathymetric anomalies which may be identified by a re-examination of the CHS work sheets.

- It is recommend that field trials be held in the Fraser Delta area to perfect suites of geophysical equipment, bathymetric techniques and sampling tools before taking them to the Beaufort Sea.